**Socio-Technical System Design**

**Brian Peacock**

**Socio Technical System Design**

# STUDY UNIT 1

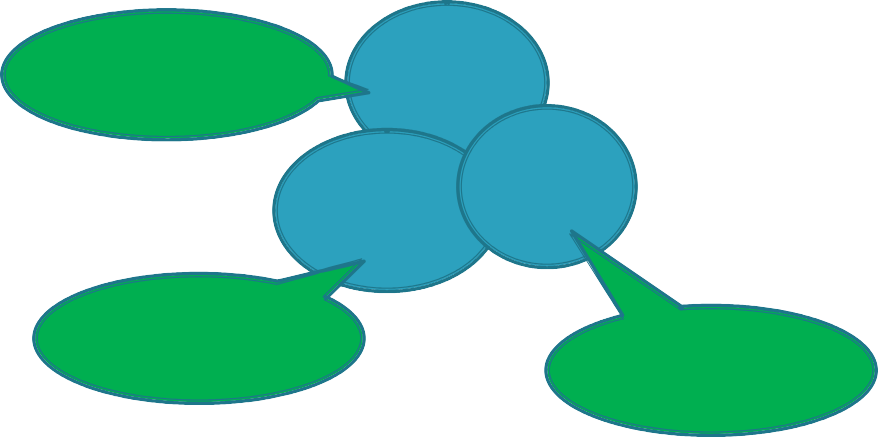
# Introduction to Ergonomics and Socio Technical Systems (STS)

## Purposes of Ergonomics – like the purpose of all system designs

* + 1. E3S3 Outcomes
       1. **Effectiveness** – The product or service meets customer quality expectations
       2. **Efficiency** – Productivity – optimal use of resources (people, money, materials, equipment, energy etc.)
       3. **Ease of Use** – Human interaction with the product or service should be convenient, comfortable and error free
       4. **Safety** – The system (product, service) should not fail and cause harm to the user, associated hardware, the environment or the organization.
       5. **Security** – The system should be resilient to malicious or accidental interference by third parties.
       6. Satisfaction – All users of the system should be satisfied with their experience and be motivated to continue to use the system

## Scope of Ergonomics

1. Body (Physical), Mind (Informational) and Soul (Social)
2. All people bring all three interacting components to all processes



**In one package!!**

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**Motivation**

**Information**

Soul

Mind

* Communication
* Cooperation
* Conflict

Body

**Energy**

## STS, Macro Ergonomics and HFACS foundations

1. The concepts of STS were developed by the Tavistock Institute whose social scientists introduced and integrated the social component in a formal way following earlier specialized approaches to physical and information ergonomics and various attempts to address the social dimensions of work.
2. Macroergonomics, a term conceived by Hendricks and Kleiner articulated a top down STS approach to the design of complex systems, coupled with bottom up participation. The process of “participation” by rank and file employees may be through a paternalistic management or through negotiated, sometimes adversarial pressure from trade unions.
3. HFACS (Human Factors Analysis and Classification System) was conceptualized by Shappell and Weigman as an accident analysis process, initially developed for the aviation domain but which can also be applied in any other domain, and to design. HFACS is a comprehensive approach that addresses:
   1. The unsafe act (human failure)
   2. Preconditions for the unsafe act (including hardware and context)
   3. Supervision
   4. And the Organizational safety climate.

# Terms and Definitions

1. **Micro ergonomics** – The scientific study of human characteristics, capabilities and limitations applied to the design of products, equipment, services and environments.
2. **Macro ergonomics** – A top down socio technical systems approach to the analysis and design of complex system integration.
3. **Ergonomics** – the amalgamation of Macro and Micro ergonomics

It may be argued that ergonomics is by definition comprehensive and should not require any qualifiers, such as physical, information or macro, as these only serve to fragment the approach. However, where some level of operational focus is convenient, care should be taken to address the possible interactions of other factors in task behavior and performance.

# Micro and Macro Ergonomics (p5)

* 1. Micro ergonomics deals with limited scope issues including:
     1. Anthropometry and workplace design
     2. Biomechanics and manual materials handling
     3. Work physiology and physical fatigue
     4. Sensory processes and information display
     5. Attention processes and information display
     6. Cognitive processes and information display and processing
     7. Motor skills analysis and task design
     8. Design of controls
     9. Communication, cognition and control theory related to process design
     10. Environmental analysis and human performance
     11. Social context of behavior and performance
  2. Macro ergonomics – a top down / bottom up socio-technical systems approach to the design of work systems and the application of the overall work system design to the design of human – job, human-machine and human- software interfaces.

# Shortcomings of traditional design of complex systems

## Technology centered design

1. Frequently the strategy of developing technological solutions to problems results in an incomplete product or service that may be ineffective, inefficient, difficult to use, unsafe, insecure and unsatisfying to the human user. Often such designs require considerable human intervention to be effective and may fail if the human requirements are not met.
   1. “Automated / E-Ticket” airline check-in requires considerable “help” for problems and passengers who do not understand the process.
   2. Many “automated machines”, such as presses, require human operators to feed in raw materials and remove finished products and scraps. These tasks tend to be repetitive and sometimes dangerous, and may also lead to quality and machine down time issues.
   3. Early grocery stores had the storekeeper bring the goods, pack them and take the customer’s money. (Sometimes they even delivered the goods). As the industry grew with more customers, the only role of the shopkeeper was to stock the shelves and take the money – the customers collected the goods from the shelves. The micro ergonomics task of the cashier is onerous and fatiguing and may lead to errors and customer dissatisfaction.

Contemporary supermarkets have automated checkouts, but store personnel are always on hand for problem solving and to monitor customer honesty.

## “Left over” approach to Function and Task Allocation (p11)

1. Where mechanization or automation is incomplete, humans are assigned to the residual tasks.
   1. Airline baggage handling has many residual human links in the process, leaving the human vulnerable to injury, especially the counter clerks, who are predominantly female and not physically capable of dealing with the heavy bags.
   2. The HK Mass Transit Railway is “fully automated” – the train starts and stops itself at each station and adjusts for headway variance. But there is an operator (in Singapore the bus driver is called the Captain) to deal with residual issues related to passenger behavior and track / vehicle / system discrepancies and to let the passengers know that there is a driver in charge, not a computer.
   3. UAVs (Unmanned Aerial Vehicles) or UASs (Unmanned Aerial Systems) do not have an onboard pilot. They are controlled remotely from the ground with more or less elaborate teams of operators. This is an advantage in conducting wars remotely; also civilian surveillance (traffic, pipeline, forestry, agriculture, border security etc.) may have many advantages of eliminating the need for human pilots. However the ground based “pilot / operator” is not committed and may be distracted or susceptible to many human failure modes such as fatigue, perceptual errors (with the onboard video systems) and less commitment to safety.

## Failure to consider Socio technical complexity (p11)

* + 1. Simplistic system designs may not be resilient in their interactions with human and environmental conditions

1. Large lecture classes and “objective” grading, aimed at productivity, are not conducive to effective learning – the students at best must follow up outside class or at worst not attend and just “read the book”
   1. Participative and interactive strategies, with inquiry components, supported by off line study have been shown to be effective for the transfer of knowledge and the development of useful outside world skills.
2. Complex systems require humans to detect, assess and counter human variability.
   1. Aviation security requires sophisticated automation plus human sensing to detect intruders with malicious intent.
      1. Anticipatory systems that combine information from many human and automatic sensors will always require human aided automation
   2. Many computer based information system interfaces are surrounded by paper notes to supplement user short-term memory. The “windows” and “applications” concepts although powerful tools still require human integration for the system to be successful and error free.

## Criteria for STS design

1. Consider the system as a whole, including the context of operation and the intended users and foreseeable misusers.
   1. Use FMEA, the 5 Whys and HFACS to track the root cause of an apparently simple accident, such as a slip or trip on a sidewalk. (These techniques will be discussed in depth later in the course.)
   2. Describe a private university from the STS viewpoint using a concept map.
      1. Describe the requirements of the various constituencies
2. Consider the human contributions at all times
   1. The is no such thing as automation
      1. There are always designers, managers, users, maintainers, customers etc.
      2. Read Kurt Vonnegut’s “Player Piano” – a satirical account of the automation utopia
3. Use concurrent design approach
   1. Design the system, the development / manufacture of the system, system implementation and system operations monitoring as a concurrent exercise, with iterative modifications



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Feedback / Lessons learned

Operations Design

Operations Implementation

Sequential paper or computer models (“walls”) of the hardware / software development status

System Design

Process Integration

Process Design

**Time to Market**

*Concurrent Engineering*

**Stage Reviews**

Mission Design

**The (Manufacturing System) Design Process**

# History of STS

1. **Taylor** – Scientific management, prescriptive task design, “line workers should not be expected to think”, short cycle work.
2. **Ford** – the production line, work simplification, productivity focus, help for the line worker by reducing non-value added activities, such as fetching and carrying.
3. **Hawthorn** – effect of social factors (attention) on job performance that confounded the main experimental variable of lighting levels.
4. **Maslow** – the hierarchy of human needs (physiology, safety, social, esteem, self actualization). Maslow argued that this was a monotonic progression with the lower levels needing to be satisfied before the higher ones could be achieved. Many people do not achieve the higher levels in their jobs, sometimes because attention to the lower levels is incomplete.
5. **Herzberg** – intrinsic motivation and hygiene factors (dissatisfiers). Herzberg argued strongly that people are primarily motivated by the intrinsic content / challenge of their work. Other factors, such as environment, supervision and even pay only serve to dissatisfy the worker.
6. **Tavistock Institute** - formal approach to the study of integrated socio technical systems following observations of failed implementation of mechanization and automation. The initial investigation was related to the introduction of automation in coalmining, which served to divide and separate team members who had hitherto considerable group cohesion.
7. **Macro Ergonomics** - a term coined by Hendrick to describe a broad, integrative, human centered approach to complex system design. Many of the case studies referred to in the book focus on three issues – management buy in to the need to address employee needs other than wages, worker participation at various levels of decision making in the organization and broad attention to many micro ergonomics issues.
   1. It may be argued that the micro ergonomics interventions may sometimes be cosmetic and subject to the “Hawthorn” effect, whereas other micro ergonomics factors may in fact address the primary needs of workers.
   2. The participation and micro ergonomics contributions in the automobile industry during the 1990s had full management support, albeit with pressure from the government and the unions. However the bottom up micro “solutions did not always address the more fundamental problems of product / component design and the inherent shortcomings of production line work.
      1. See handout on “Fatigue and the job cycle”
8. **Woodward** – described the structure of organizations from the STS viewpoint (unit, batch, mass, process production)
9. **Deming** – a statistician credited with large improvements in quality in Japanese industry; argued the case of “the honest worker” who just wanted to do a good job, also distinguished between common causes of variation and special causes, which required attention.
10. **Volvo** – Teams of assemblers followed a unit along the assembly line. Vehicle rotated for better access to the underbody. Widely supported by Swedish organized labor with its participative approach to job design.
11. **Saturn** – A joint GM – (Independent) Union managed facility. Work teams with job rotation, equitable shift systems, and final assembly on height adjustable palettes for easy access. Many innovative processes, tools and vehicle designs with assembly in mind. Very high levels of worker participation at all levels of management. Ergonomics teams very active in problem solving. The system broke down in the late 1990s when the central union (UAW) was voted in by the employees and the Saturn division became like all other GM divisions.
12. **General Motors, Lansing Craft Center** – In general assembly the vehicle does not move on a production line, rather it is surrounded by a team, baskets of components, tools and fasteners where it is completely assembled and tested before moving to final inspection. The whole GA process takes about an hour per unit. Substantial employee input to product, manufacturing process and task content design.
13. **Toyota Production System** – a formal top down, prescriptive (e.g. 5S – Sort, Set in order, Sweep, Standardize, Sustain) job design process that makes use of operator teams (e.g. quality circles) and knowledge related to process quality, productivity and safety. System performance is monitored by visual controls, often taking the form of control charts. Introduction of the andon chord which allowed anyone to stop the line when a problem arose – all affected workers, including skilled trades and engineering would congregate to resolve the problem.
14. **South West Airlines -** Employees first, no first class, first come first served seating. Many strategic cost saving policies – only short haul domestic flights, fleet limited to B737, introduction of winglets to reduce drag, wake turbulence and improve handling, no pre assigned seating, no first class, lower salaries but better benefits etc. Most successful N American airline.
15. **General Motors Manufacturing Ergonomics Program** – Development of center of ergonomics expertise in corporate manufacturing engineering. Parallel development of training center in UAW Center for Health and Safety.

Development of checklists / analysis tools. Training and assignment of salaried and hourly ergonomics specialists in every plant. Training and assignment of ergonomics specialists in car programs. Development and deployment of reactive and proactive ergonomics programs. Deployment of programs throughout North America and Europe. Task force approach to difficult problems such as installation of intermediate shaft, hoses, batteries, wheels / spare wheel, wind shield wiper motor, seats, exhaust system, wiring connectors etc. Some addressed by engineering interventions, some by administrative controls.

1. **Politicization of Ergonomics** – Accelerated with a tripartite agreement between the US Department of Labor, The UAW and the Big Three Automobile manufacturing companies following previous agreements in the meatpacking and retirement home industries. Followed by the pursuit of an ergonomics standard by the US Department of Labor, managed by joint management and worker / union representatives, to reduce the incidence of work related musculoskeletal disorders.

This standard was generally supported by the ergonomics community as a formal way of introducing ergonomics methods both reactively and proactively. This was a bottom up “political” process in contrast to the top down (management manage, employees participate) process of the Toyota Production System. The ergonomics standard was introduced by the Democrats and immediately cancelled by the Republicans. Throughout the developments management set up an opposition through the National Association of Manufacturers and The US Department of Commerce. (see hand out – An alternative ergonomics standard)

1. **Costs and Benefits of Macro Ergonomics**

## Benefits

* + 1. The benefits of Macroergonomics are through a combination of management commitment and employee participation leading to many micro ergonomics improvements which in turn lead to:
       1. Improved effectiveness (quality)
       2. Efficiency, improved productivity, optimal use of resources
       3. Ease of use, reduced human errors, rework
       4. Safety, reduced costs by accident prevention, reduced injury and damage to equipment and the environment
       5. Security, reduced susceptibility to accidental and malicious system interference
       6. Satisfaction, improved quality of work life and motivation, improved customer satisfaction
       7. Reduced skills and training
       8. Reduced waste
       9. Reduced maintenance – first line maintenance by operators (TPM)
    2. Profit (and cost) sharing is the ultimate level of participative management of organizations especially when rewards are tied to tangible contributions.

## Costs of Macroergonomics

1. Added form of bureaucracy – nothing is done without full participation – more meetings
2. Time needed for analysis and design
3. New equipment
4. Reorganization barriers
   1. Interference with production during reorganization
   2. “Not invented here”, “We have always done it this way.”
   3. Job responsibility changes up and down the management chain
5. Increased training for rotation and enlargement (vertical and horizontal) skills
6. Difficulty in objective assessment of Macroergonomics interventions.

# Macro Ergonomics Implementation

1. **Macro ergonomics aspirations** are rarely the province of the macro ergonomist, rather top management must become attuned to the principles of macro ergonomics, by whatever name.
   1. The Industrial Relations / Human Resources departments grew to assist management with personnel issues, such as hiring and firing, wages and benefits, health and safety, and negotiated work conditions. The HR department rarely got involved in production operations
   2. Macro ergonomics sees a more collaborative rather than prescriptive world, but relies on the established processes / departments for multiple, specific micro ergonomics interventions..
   3. Top down / bottom up philosophy
      1. Top management must support, employees/ customers should participate at all levels of decision making
      2. Alternatively Macro ergonomics can be implemented top down with employee cooperation, but without “vertical enlargement”
   4. GM macro ergonomics program was a participative effort, supported by top management and union leadership with center of expertise within manufacturing / industrial engineering, and within vehicle programs.
      1. Involvement of GM Europe hampered by considerable resistance to top down (Detroit centered) process; resolved by collaboration.
2. **Macro ergonomics implementation** varies according to organization structure(s) (p16)

### Product centered

* 1. Manufacturing (e.g. automobile, electronics, textiles, plastics)
  2. Retail – labor differentiated between purchasing, processing, transportation and the retail front end with shelf stocking and checkout operations
  3. Construction – many skills brought together (serially) to create a single product, organized by general contractor who arranges just in time materials delivery and sequential structure and services operations
  4. Efficiencies in product centered organizations generally lead to mass production strategies and work simplification
  5. Macro ergonomics implementation in vertically differentiated organizations must come from the top, with employee participation
     1. Alternative model of joint responsibility leads to conflicts of process and domain / technical ergonomics knowledge.

### Function centered

* 1. Hospital
     1. Differentiation of knowledge, skills and activities – specialties – both medical and service departments (therapy, X ray, labs etc.)
     2. Growth of independent and competitive (for budget, space and equipment) departments
     3. Specialist medical knowledge and skills requiring very different resources – costly equipment, operating rooms etc.
     4. Specialist service departments (X-ray, biochemical testing, rehabilitation etc) also compete for budget and growth
     5. Growth of hospitalist / general medical practitioner to deal with all other aspects of the patient’s situation.
  2. In aviation there must be cooperation between the captains, the rest of the flight crew, air traffic control (center and en route), dispatch, maintenance and fueling, passenger management, and their respective organizations.
     1. Crew Resource Management (CRM) developed to assure effective collaborative activities among all the human, technical and administrative “resources”
  3. Macroergonomics implemented in horizontally differentiated / function centered organizations requires the buy in / participation of the experts / specialists, who defend their own territory aggressively. Difficulties of implementation arise due to professional as well as administrative hierarchies, and operational focus around knowledge and experience.
     1. CRM concepts are applied in both aviation and medicine and face resistance from a long history of expert centered management traditions that vary with national / ethnic traditions.

### Hybrid

* 1. University
     1. Specialized departments / degrees / subjects
        1. Can become product centered with vertical separation
     2. Competition for growth, space, equipment, budget
     3. Student may be narrowly trained
     4. Professors become specialists in order to publish
        1. They become professional experts
           1. Collaborate (and sometimes compete) with professional peers
           2. Lead their junior colleagues and graduate students
           3. Function centered / independent laboratory structure
        2. Must teach more generally – basic material
           1. This requires team work
           2. Experts subservient to administration for such things as classroom / time slot allocation, teaching load, examination format
     5. Pressure on the curriculum as knowledge in a subject area grows
        1. Further subdivisions, new function centered organizations
        2. Conflict over priorities arises
     6. General education requirements became targets for removal / minimization
        1. Humanities, business, arts, language etc for engineers.
        2. Technology awareness for arts and business students
        3. Computer and communications literacy
     7. Technique specialization
        1. Research methods
           1. Laboratory data capture and statistical analysis skills develop in a function centered format around the expert
        2. Teaching methods – influence of education process experts on teaching methods
           1. Leads to balance between teaching (top down) and learning (participative, inquiry)
           2. Balance varies between subject and level
        3. Computer skills overlaid – all participants require common computer skills plus specialist computer package knowledge such as Statistics, MATLAB, and Simulation etc.
  2. Large vertically differentiated organizations (e.g. automobile manufacturing) also rely on horizontally differentiated technology centers that may overlap:
     1. Safety, ergonomics and industrial hygiene
     2. Robotics, paint and welding
     3. Styling, engineering, marketing and program management

1. **Complexity**
2. Vertical and horizontal differentiation occurs with growth
   1. Departments, levels, titles
      1. Manager, director, vice president, president etc
      2. Leading to competition for promotion
   2. Horizontal differentiation may be accompanied by overlapping sub specialties
      1. E.g. Ergonomics, safety, industrial hygiene (see above)
      2. Leading to development on small independent hierarchies and opportunities for horizontal competition for resources
3. Integration / coordination / communication challenges
   1. Development of parallel hierarchical committee structures
      1. Overlap and separation of responsibility among permanent committees and limited duration task forces creates opportunities for conflict
      2. Competition of committee hierarchy with line management for authority
4. Varying degrees of formalization – well defined structures, processes and outcomes
   1. Rigid structures breed integrated teams (interdisciplinary, cross functional, product development teams)
   2. High degrees of formalization with vertical differentiation usually lead to limited life task forces rather than standing committees
5. Centralization
   1. Perceived better control by higher levels
   2. Counter argument of “autonomy with responsibility.”
   3. Major challenges for international companies
      1. General Motors best practice / common process policies presented challenges between international centers, and technology centers
      2. Considerable pressure for regional autonomy
6. Hierarchy
   1. Vertical separation
      1. (Compare General Motors (19 levels) and the Catholic Church (4 levels))
      2. Span of control
         1. Flat organizations
            1. Project leads – individuals have different roles in different projects
            2. Become unwieldy as organization grows

Needs for specialized departments

Human “need” for “promotion”

Administrative functions better dealt with by small span of control.

* + - 1. Deep hierarchies (vertical differentiation) causes and shortcomings:
         1. Usual result of company growth
         2. Usually occurs in product focused organizations
         3. Promotion of managers an unspoken primary purpose
         4. Vertical and horizontal communication difficulties
         5. Parallel committee hierarchies

Committees fight with line management for control

## Distribution

1. Departmental separation
   1. Autonomy – departments seek independence
   2. Separation of functions – line and support organizations
      1. Line organization, personnel, quality, safety, accounting etc.
   3. Overlaps – departments try to grow in space, responsibilities, budgets and influence
2. Geographical separation
   1. Different products / models at different plants
   2. Component suppliers – local, international
   3. Specialized central technology and support centers, distributed production facilities
      1. Central -Design, engineering, marketing, personnel, safety etc
      2. Distributed – components, assembly
      3. Travel budget increases!!
      4. Communications costs and time
      5. Pressure to set up local technology / service centers in horizontally separated units
3. Subcontracts – many advantages
   1. Lower labor costs
   2. Geographically separated
      1. Often overseas or non unionized
   3. Lower overheads
   4. Specialized component knowledge
   5. Conflict on price with OEM (Original Equipment Manufacturer)
      1. Supplier cost engineering squeeze
      2. Disadvantages
         1. Quality control may suffer
         2. Component cost will creep
         3. Specifications changes cause large cost increase
   6. May be many layers – OEM, first, second and third tier suppliers
      1. Communication and transportation challenges

## Communication and contemporary technology

* 1. Essential part of distributed organizations
  2. Meetings
     1. Face to face, teleconference
     2. Chats
  3. Asynchronous communications
     1. E-mail
     2. Blogs, social networks
  4. Intermediate technology seen as barrier to efficient operations / communications when compared with face to face meetings
     1. Proliferation of e-mails, voice mails, etc. is a major time consumer for managers who are unnecessarily “copied” on messages.
     2. Face to face meetings also have difficulties due to geographical separation, scheduling problems and uncontrolled divergence.

## Efficiency

* 1. Autonomy with responsibility often seen as a major motivator leading to the establishment of small independent groups
  2. Local autonomous units internally efficient but may not see the big picture resulting in suboptimization

## Macro Ergonomics contributions

* 1. Systematic way of articulating the structure, process and outcomes of large systems
  2. Macro ergonomist as advisor to management
     1. Must use domain knowledge to complement Macroergonomics knowledge and tools
     2. Should identify the “low hanging fruit” to motivate management to continue support
        1. Quality, productivity, satisfaction, safety
     3. Must be succinct – managers in industry and business do not have time to read the details of the communications from all their individual, committee and departmental reports
        1. General Motors and NASA HF instituted a process of one page reports (supported where necessary with back up material)

# Handouts

* 1. Purpose and Scope of Ergonomics in Design
  2. Concept mapping
  3. “Job redesign in the bindery

# Case Study – Bookbinding

### The problem

* + 1. The book bindery at HKU put hard copies on paperback books and annual collections of journals
    2. “work in progress” could be many weeks
    3. Low “status” of the blue collar bindery staff in a white collar (library) environment
    4. Equipment bottlenecks
    5. Inefficient project management / scheduling
       1. Informal priorities due to status differences between academic department heads and bindery manager.
    6. Poor environmental context – heat, noise, glare
    7. Narrow job responsibilities based on seniority

### The solutions

* + 1. Reorganized storage and categorization of binding requests
    2. Just in time delivery of raw materials / journals / books
    3. Batch work flow
    4. Introduced team structure
       1. Team carried a batch of similar material (based on group technology principles) through the whole process
    5. Vertical job enlargement – all staff were trained to carry out all stages of the bookbinding process
    6. Slow job rotation (later changed from 1 day to 1 week at the request of the bindery staff)
    7. New equipment to resolve bottleneck problem
    8. Addressed environmental issues (carpets, blinds). These “microergonomics” interventions were much appreciated
    9. Placed “white collar” buffer between bindery and library staff to resolve informal priorities issue
    10. Across the board pay raise (pay for performance) – very much appreciated

### The results

* + 1. Large increase in productivity
    2. Greatly reduced “work in progress” delays
    3. Generally improved morale

### The conclusions

* + 1. Major success of Macroergonomics intervention
    2. The “Hawthorne effect” questions remain



**EXERCISE:**

1. Develop bibliography of STS key words / contributors
2. Use Internet search / Wikipedia and Google Scholar

# Self Test Questions

1. List and describe the 6 general purposes of ergonomics, with examples(1)
2. Define Macro ergonomics
3. Give 6 examples of micro ergonomics
4. List 3 common failures of not considering STS issues
5. List 10 key people / companies that contributed to the development of Socio Technical Systems
6. List 10 costs and benefits of applying Socio Technical Systems approach
7. Give 3 examples each of Product and Function centered organization designs
8. Describe 3 forms of complexity in large organizations
9. How can large organizations be “distributed?”

List 3 key points in communicating macro ergonomics advice to management and implementing macroergonomics issues.

**Socio-Technical System Design**

**Study Unit 2**

# Introduction

Socio technical system design has many process similarities to technical system design

# Process and system design fundamentals

Monitoring, Anticipating, Responding

*Concurrent Engineering*

Feedback / Lessons Learned / Technical Memory

Operations Implementation

Analogs, Modeling

Operations Design

Time, Resource and Activity Planning, Modeling

Process Integration

*Overlapping sequences of requirements, design activities and verifications*

Navigating, Launching, Eating, Exercising, Landing, Modeling

Propulsion, Biomass Production Equipment, Communications Equipment, Robots

Process Design

System Design

The Design Process

Manned Mars Mission

Mission Design

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Information Feedback

Reviews (Verification)

Activities

One Step in the Design Process

**Properties**

Reviews (Validation)

Guidelines Requirements Specifications

**People**



The Classroom Analogy

The Course

Feedback?

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People – Professors, Students, Assistants, Subjects

Properties – Notes, Books, Presentations, Discussions, Laboratories, Computers

Department Reviews

Test the performance requirements

Exams

Test the specifications

Classes, Labs and Homework

Syllabus

1. Should “participants”, “customers” and “stakeholders” be used interchangeably?
2. The Grammar of Design – design as a communication process is accomplished more effectively and efficiently, with less error and rework if participants (including customers) adhere to a common language. The following operational definitions are presented to support this process.
3. Systems and processes
   1. A system is described by a noun and measured (qualified, quantified) by an adjective
   2. A process involves the interaction of two or more systems. It is described by a verb and measured (qualified, quantified) by an adverb. A process will usually result in a change to one or more of the participating systems.
4. Systems analysis addresses Structure, Process and Outcomes
   1. Structure – the tangible components of a system
   2. Process – the interactions among system components
   3. Outcomes – the change in state of one or more system components as a result of the process
5. Requirements and Specifications
   1. A process has performance requirements as set by the various customers; performance requirements are measured by reference to some standard or by comparison with other processes.
      1. Performance may be measured by a change in subsystem / component state
      2. Requirements will generally be classified into
         1. E3S3 - Effectiveness, Efficiency, Ease of Use, Safety, Security,

Satisfaction

* + - 1. Often a customer may desire high levels of all of these outcomes, but may have to settle for a compromise
  1. A system has specifications, usually quantitative, that are necessary for design
     1. Adjectives!- big engine, dry road, trained driver, restrictive speed limits

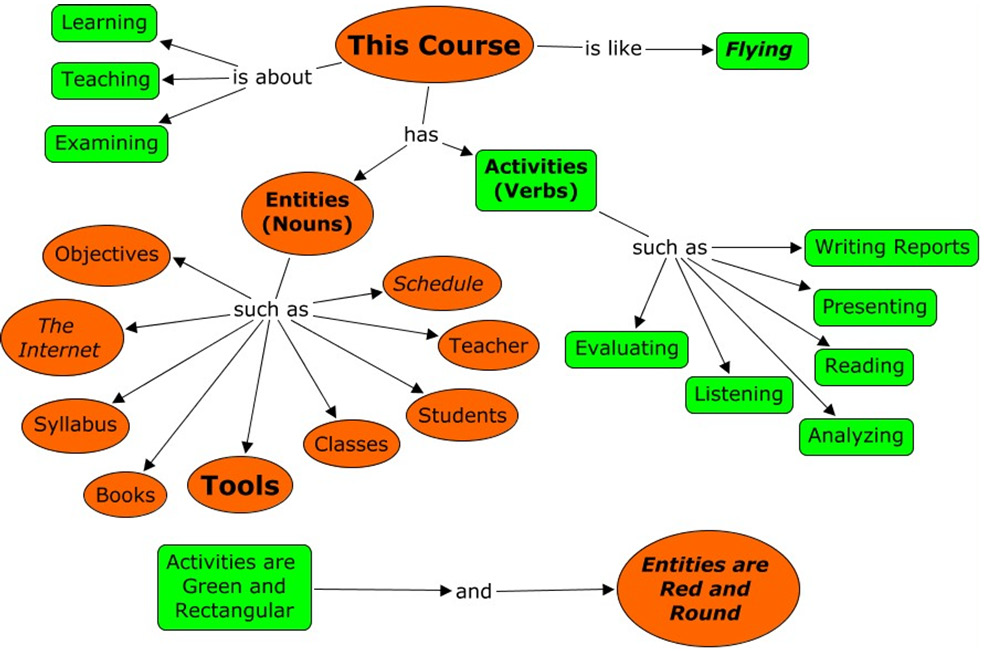
1. Validation and Verification
   1. Processes are validated by being implemented in a realistic context (environment, users etc) or simulation.
      1. Driving involves human, vehicle, environmental and regulatory subsystems
      2. Driving quickly involves all these subsystems
      3. Driving “quickly” is relative to other occurrences of the driving process which has different subsystem values
      4. Driving safely involves all of these systems and may not occur if one or more of the subsystems is “out of tolerance”

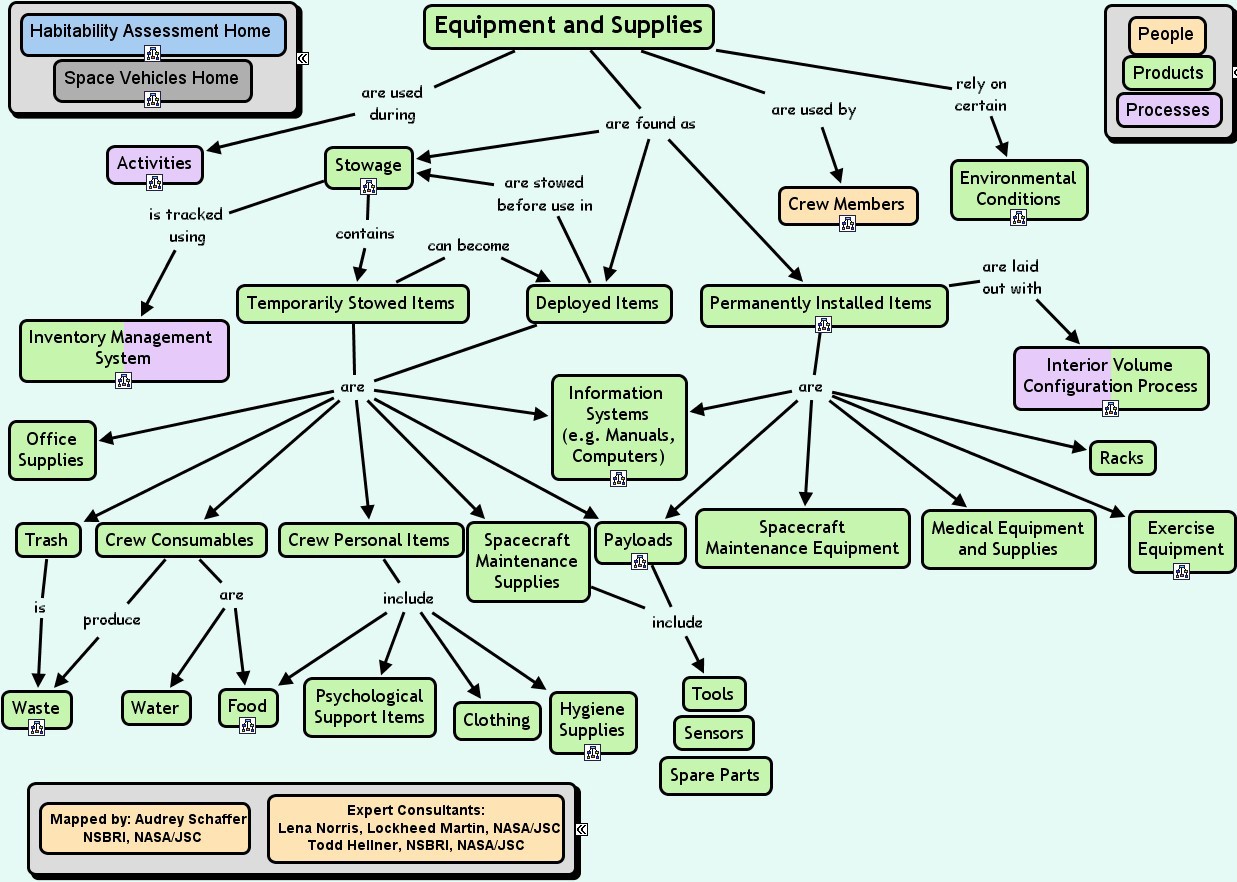
Driving quickly and safely depends on high levels of all the subsys

* 1. Systems are verified objectively by measurement of key features (adjectives) and comparison with the system design specifications (with tolerances)
     1. Big engine – V8
     2. Trained driver – attended and passed safe driving course
     3. Restrictive speed limits – 50 kph

# Concept maps

1. Concept maps are a diagrammatic way of describing a complex situation, system or process showing key sequences, interactions and links to supporting information
   1. <http://cmap.ihmc.us/conceptmap.html>
   2. <http://cmap.ihmc.us/download/>
2. Adaptations of concept mapping will be used throughout the course to assist in organizational structure and process analysis.
3. An operational discipline in concept mapping is to separate activities (processes) from entities (systems) and apply “grammar of design” concepts

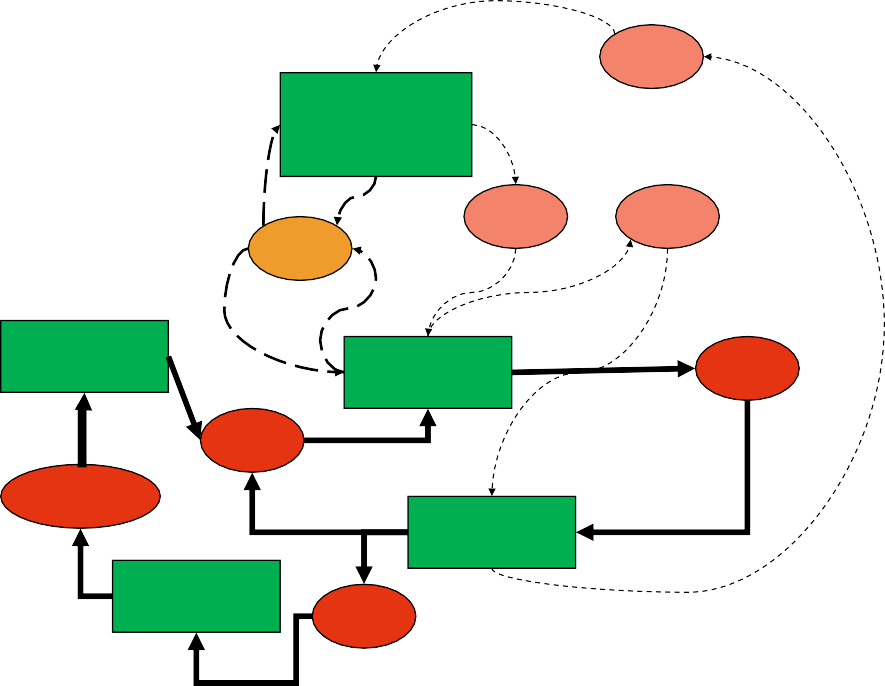




# Activity Cycle Diagrams

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1. A graphical way of describing the flow of entities / resources around a complex network of activities and queues based on embedded logic. Can be used for complex system description or as a basis for discrete event simulation.
2. Each entity will move around a different activity cycle consisting of activities and queues (times when the entity (system) is not being used)
3. Activity cycle diagram concepts will be used throughout the course to describe complex systems and processes.
4. Check the activity cycles and branching logic of the following activity cycle diagram that shows the resources (entities), activities and pathways associated with a bar or café.



25

25

Customer

Leaves

Customer

Drinks

Customers

Customer

Queue

Customer

Served

Customer

Arrives

Full

Glasses

Clean

Glasses

Waiter

Queue

Collect and

Wash Glasses

Dirty

Glasses

**A Bar**

# Design Process

## The Human Factors Cycle

* + 1. The human factors cycle is superimposed upon the general process model (inputs – process – outputs) by adding both process and outcome analysis and the decision process used to modulate the inputs based on process and outcome analysis. Furthermore the inputs are separated into those factors that can be changed and those environmental / context factors that usually cannot be changed, but which must be considered in system and process design.



**The HFE Cycle**

**Evaluation** (Processes, Systems and Outcomes)

**Screening Analysis** (Process and System Design)

**Mission Job Task**

**Simulation**

*What* ***can***

*be changed*

* Organization
* Humanware
* Interfaces

**Design (Processes and Systems)**

* Hardware
* Software

*What* ***cannot*** *be changed*

* Physical
* Chemical
* Biological
* Psychological
* Social
* Organizational
* Financial

**Environment/Context**

* Spatial
* Mechanical

**Decisions**

* Risks
* Benefits
* Costs

**In Depth Analysis** (Process and System Design)

**Outcomes:**

* Quality - Effectiveness
* Productivity - Efficiency
* Safety – Acute
* Security
* Health - Cumulative
* Motivation - Satisfaction

## Design as a control problem

**P**

35

**B**

**E**

Analysis

Feedback

Decisions

Risks Benefits

$$$$

Outcomes

E3S3

Simulation

or Process

Design

People Equipment Information Organizations

Mitigation

Design for Failure

Context

Environment Time Organization

Analysis

Feedforward

Ergonomics Process

1. Inputs (systems)– must be designed
   1. Human inputs– affected by selection, training, assignment, abilities, limitations, motivation, attention, fatigue, etc.
   2. Equipment and materials – can be designed, must be resilient with regard to users and context
   3. Context / environment – cannot be designed, must be addressed, for example by barriers or shields
   4. Regulations may be applied to Human, Technology and Environmental subsystems
      1. Passed driving test, Energy efficient car, Day time driving
2. Process
   1. The interaction of two or more systems with a measurable outcome in terms of process performance and the change in state of one or more contributing systems
3. Outcomes
   1. Generally measured in terms of:
      1. Effectiveness - quality – matching customer requirements
      2. Efficiency – optimal use of resources (money, time, materials, energy, people etc.)
      3. Ease of use – resilient to varied users, usage and contexts
         1. See 6Us handout
      4. Safety – systems resilient to catastrophic failure, wear
         1. Process / system failure mitigated to reduce severity of unwanted outcome
      5. Security – process / systems resilient to accidental or malicious interference by third parties.
      6. Satisfaction – (all) human users (customers) should be satisfied by their experience with the process /systems
         1. There may be compromises
4. Feedback, adaptation and learning control
   1. Feedback – mechanism for communicating outcomes (error) to modulate inputs
      1. Flying in wind under Visual Flight Rules (VFR) conditions
      2. Catching a ball
      3. Balancing on one foot
      4. Heart rate (what about anticipatory heart rate increase?)
   2. Adaptive – automatic adjustment to inputs based on pre-defined context
      1. Thermostat – heating / cooling changes to pre selected conditions
      2. Jockeying in queue behavior
      3. Diabetes medication
   3. Learning – behavior modification and performance improvement with experience / practice
      1. Hitting a golf ball
      2. Driving
      3. Taking examinations
5. Feedforward (anticipation)
   1. Prediction of the effects of context on the process behavior, modulation of inputs (subsystem changes) accordingly
      1. Environmental, technology or regulatory context etc.
   2. Necessary for the design of resilient systems – systems that can withstand the effects of intended and unexpected context and time
      1. Market research
      2. Weather planning
   3. Feedforward information may be erroneous or at best probabilistic
      1. What will the other driver do?
      2. Will it rain / snow / freeze today?
      3. Will the technology subsystem (e.g. car) deteriorate over time or without maintenance?
   4. Human beings usually make considerable use of “feedforward” / anticipation
      1. This activity often leads to timely actions that may be in error due to uncertainty in the anticipation process as in choosing a menu item based on a verbal description, preparing answers to questions at an interview, designing an advertisement aimed at a subset of customers or selecting a technology for fuel efficient cars.
      2. Market research is a mechanism used to predict customer needs and wants in the future. However as product (e.g. car ) design take a few years and operates in a competitive context these customer requirements may be a “moving target”
6. Decisions regarding process inputs are usually made with reference to the cost of resources such as money, time, people, equipment, fuel, materials etc.
   1. The Socio Technical System Design philosophy will face decisions by managers who may be more focused on technology than the vagaries / requirements of multiple customers / stakeholders
   2. Decisions are usually the prerogative of management
   3. Decisions in the design process are usually made in the progress review meetings where the components, including HFE advice are presented in the context of the big picture.
   4. These decisions will be biased by the managers’ / committee prejudices and the ability of the engineer to sell his or her point of view.
      1. Effective communication is a learned skill – practiced in the classroom in preparation for the workplace.

## Design as a Communication problem, using car design as a case study

Physical Decoding

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11/11/2009

Semantic Decoding

Feedback

Transmission

Noise and Lost Information

Memory

Physical Encoding

Semantic Encoding

Concept

Communication Models

1. Concept / idea of someone involved in a design or purchase process
   1. An economical family car (requirements)
2. Semantic and Physical encoding
   1. *Semantic encoding* – translating the idea into some known language, diagram, model etc
      1. Using automotive jargon – “ a mid – size, base level sedan” – relative statements / requirements
   2. *Physical encoding* - Translating the conceptual model into an explicit physical form, such as drawing, writing or speaking
      1. 4 seat, four door, sedan with cloth, automatic, Quad 4, entry level IP
         1. Note use of jargon and abbreviations
         2. There are many variations / interpretations of this initial verbal set of high level specifications
3. Transmission, Noise, Added information
   1. Transmitting the idea to the intended (unintended) audience
      1. The transmission may involve a series of translations by individuals with different priorities
      2. Note that the idea may not be clearly articulated (lost in translation – omissions, additions, changes)
      3. Note also that there may be external physical or informational “noise” during the transmission process
      4. The full message may not reach the intended recipient for a variety of technical reasons
4. Physical and Semantic decoding by multiple customers with different priorities
   1. Manufacturing, maintenance, sales, drivers, regulators etc.
      1. Receiving and understanding the information
      2. The receiver may not physically receive / sense the message
      3. Note that understanding requires knowledge of the language and a reception framework – the translation may be biased by the receiver
5. Consolidation, Retention, Forgetting, Action
   1. The receiver must consolidate (fit into his framework), remember (or forget) and translate the information into action
   2. The eventual set of high level specifications could now be:
      1. 5 seat – mid level vehicle usually have 5 seats not four
      2. Sedan heard as “van” (physical decoding)
      3. Automatic referred to gearbox, but added windows, door locks and seats – typical of less economical vehicles (semantic decoding / added information)
      4. Four door translated into two conventional front doors plus two rear sliding doors – common in vans
      5. Quad 4 engine, typical of small cars, was converted to V6 based on common choice of engine for minivans
6. Feedback, Adaptation, Learning, Iteration
   1. The originator of the idea needs feedback in order to modify the idea / concept (see control model above)
   2. The feedback cycle should reduce the communication errors. However if feedback is not available the communication may lead to designs that don’t satisfy the initial intent (requirements)
7. Design is vulnerable to communication failures and participant inconsistencies
   1. A problem similar to this actually occurred with an attempt to design a front wheel drive Camaro

# System Life Cycle

Major focus is on car manufacturing from the Socio Technical and micro ergonomics perspective

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BP System Safety Lecture 2

Life Cycle in Product Design

* Mission / Purpose
* Concept(s) design
* Concept evaluation and testing
* Concept selection
  + Design for use (Usability Testing)
  + Design for manufacturing and assembly
  + Design for service and maintenance
  + Design for disposal
  + **Design for SAFETY**
* Manufacturing and Production Design
* Production
* Distribution and Sales
* Use
* Service and Maintenance
* Disposal
  1. Consider the life cycle of a car

### *Product design*

* + - 1. The mission / purpose will vary enormously depending on the functional requirements of the intended user / buyer / customer. – a sedan, truck, sports car, luxury car
         1. The seven ages of “carman”

Teens – wheels (Civic), 20s - style (Camaro), 30s – function (minivan), 40s – prestige (Buick), 50s –lavish style (Corvette), 60s

- comfort and safety (Cadillac), 70s – wheels (Civic)

* + - * 1. The mission / purpose should consider many other customers

Manufacturers, maintainers, shareholders, regulators

* + - 1. Within each general lifecycle stage there will be subcategories, each aimed at emphasizing particular aspects of the vehicle
         1. These sub requirements will be based on generally accepted customer standards.
      2. The design process will include many iterative steps of “design – make – test– decide”
         1. These cycles will be at both the component / subsystem level and at the system level
      3. Concept selection will be based on many “weighted “ criteria
         1. Use, manufacturing, safety, maintenance, disposal
         2. Concept selection is an imprecise process carried out around a conference room table

“Votes equals opinion time salary” – seniority is equivalent to wisdom?

The front wheel drive Camaro

Conflict between engineering and marketing and management

Hard or soft seats in a Caprice

An opportunity for a psychophysical investigation

The ACCESS Car

A marketing mistake?

An engineering opportunity

A human factors driven process.

Intermediate shaft installation

Transatlantic disagreement

Battery location (engine compartment or trunk)

Engineering and manufacturing conflict

The proliferation of warnings

Conflict between human factors, marketing and legal staff

### *Manufacturing and Production Design*

* + - 1. DFM / DFA (Design for manufacturing and assembly)
         1. Aimed at productivity, quality and worker comfort and convenience

Access, easy targets, force, posture and fastener repetition reduction are the general aims

See “Tight Targets Take Time” handout

* + - * 1. Cars with pressure for a low cowl height will create engine compartment packaging challenges, which in turn lead to accessibility problems in assembly and maintenance
        2. A decision to sequence the seat install after the doors have been installed can lead to longer cycle times, mutilations during the seat transfer into the vehicle and difficult access for installing the seat belts and the seat secure bolts.
      1. Major allocation of function decisions
         1. Mechanization and automation

Articulating arms very useful for heavy components / subassemblies

Often found tied to a pillar for intermediate weight components

The job is possible without the arm

The job may be faster without the arm

The repeated load may give rise to injury

Robotic undercoat and paint spraying is the norm, but robots cannot easily access certain inside facing areas such as the bottom of the doors which need to be painted by human operators, who have to sustain awkward postures throughout the job cycle, giving rise to quality and injury problems

Cleaning the paint booths of residue is a largely residual manual task. Pulling grates is a difficult and physically stressful task.

* + - * 1. Tool selection

Threaded fasteners are usually torque controlled. Task completion often induces a stressful torque reaction, giving rise to injury. This is sometimes reduced by a torque bar but alternative technologies such as hydraulic/ pneumatic / electric pulse tools can remove the torque reaction problem with no loss of quality (torque control)

Inline, pistol grip or right angle tools can sometimes be used to allow more convenient arm postures, depending on the amount of torque and the location of the fastener. Inappropriate tool selection can cause discomfort and injury

Tools may be supported by balancers, but these may interfere with task access and so may be discarded by the operator.

* + - * 1. Modular design for model differentiation/ subassembly content

Major trend to increase module content, thus reducing the final assembly operations

Steering columns include lighting, windshield, cruise control,

HVAC, entertainment and navigation functions

The module becomes heavy and awkward

The residual intermediate shaft (between the steering column and steering box) installation is a major source of difficulty for the operator

Windshield wiper motor and brake booster install

These two components are hard to reach in the center / bottom of the engine compartment respectively

Task can be made easier by product design (for the windshield wiper motor) bringing it out board and by assembling the brake booster module on a different station on the production line.

Spare tire in the bottom of the trunk is both difficult for assembly and difficult for the driver who needs to change a wheel, but a convenient place for packaging.

Product design solutions include the mini spare, which is lighter and may be packaged at the side of the trunk for easier access

Question -Does the car owner need a spare tire or a cell phone to summon help?

Seats / seat belts

Difficult install postures – seatbelts can be designed to be integral with the seat, given appropriate structural modifications, which in turn leads to a much easier assembly task.

Layering and Fastener orientation for operator access

This is a packaging and component design problem. Product design engineers should spend time on the line installing their own components to appreciate the line operator difficulties

* + - * 1. Vehicle carrier systems

Many opportunities in manufacturing design to improve operator posture

Overhead rail – bring low and underbody work to accessible height more convenient than working in pits

Tilting – rotates the vehicle 45, 60 or 90degrees to improve visual and hand tool access

Skillets – operator adjustable vertical height

### *Production operations*

* + - 1. Production targets affect staffing levels and choice of shift system (1, 2 or 3 shifts)
      2. Shift work should be based on operational, human and technological system needs
         1. Production targets
         2. Physiological and social requirements
         3. Access to equipment for maintenance
      3. Task design
         1. Will vary according to line speed and work area footprint
         2. Learning curves for job content and “experienced worker standard” assignment
         3. Balance of non value added work – carrying, walk back etc.
      4. Stock / components / fastener / hand tool presentation
         1. Aimed at reducing error, non value added time, and improving comfort and convenience
      5. Work team design / task allocation
         1. Job enlargement / rotation and team assignment philosophy
      6. Rotation and enlargement strategies
      7. Quality, productivity and safety monitoring
      8. Methods engineering
    1. ***Distribution and Sales*** – class discussion / exercise of customer requirements and design
       1. Substantial human contribution
       2. Order management
       3. Transport
          1. Protection
          2. Long distance driving / railways / container ships
       4. Brochures, warranties, financing, insurance, taxes, incentives
       5. Salesperson employment strategy
          1. Incentives, salary?
    2. ***Use*** – class discussion / exercise
       1. Buyer / driver / passenger
       2. Road ways
       3. Traffic
       4. Taxes
       5. Garaging / parking
       6. Adverse environmental conditions
          1. Night and day, fog
          2. Snow and ice
          3. Heat and cold
          4. Traffic noise
          5. Vibration
          6. Road condition
    3. ***Service and maintenance*** – class discussion / exercise
       1. Context of maintenance
          1. Tools
       2. Training of maintainers
          1. Support manuals
          2. Spare parts

Distribution strategies

### *Disposal*

* + - 1. Green car
         1. Design / materials / manufacturing cost constraints
      2. Used car market
         1. Warranties
         2. Spares availability
  1. Concurrent engineering - a delivery opportunity for Socio Technical System Design
     1. All life cycle stages, customers and stakeholders need to be accommodated
     2. Multiple overlapping steps
     3. Feedback and iteration
     4. Technical memory
     5. Evaluation
     6. Aided by adhering to the discipline of the “Grammar of Design”, including control and communication models
     7. Aided by the use of concept mapping and activity cycle diagrams

# Handouts

1. The Grammar of Design
2. The Purpose of Design
3. Concept maps
4. Activity Cycle Diagrams
5. Paper Airplane Design Exercise

|  |  |  |
| --- | --- | --- |
| **EXERCISE:**   * 1. Paper airplane design | | |
| Paper Airplane Game  **Marketing - Competition Manufacturing - Communication**   * First to market gets the prize • Specifications * Largest payload gets a prize – One piece of paper * BUT Quality Rules! – 500 units per day * Customer Requirements   + **Range 5 meters** • Less than 1 minute to assemble   + **Navigation +/- 1 meter** – Simple operations / folds   + **Payload ? paperclips**   + **Safety Land flat Operations – Customers**   + **Aesthetics Customer ratings** • Fly 3 test flights     - Score   **Design - Collaboration** • Range   * Translate Customer, Manufacturing Navigation accuracy Maintenance Requirements into * Manufacturing Specifications • SafetyAesthetics * Maintain - take apart and   re-assemble in 30 seconds | |  |
| SocioTechnicalSystems  Questions   * How did competition affect your behavior?   + Speed to market   + Space in room for all activities (crowds) * How did the team work together? - collaboration * Was communication clear?   + Between design and manufacturing * Who dominated the collaboration?   + marketing, design or manufacturing?   + Who needs management? * Who are the customers?   + Passengers, marketing, design, manufacturing, maintenance, management, shareholders * How would you design an organization to build 5 different models, each with500 units per day, with manufacturing plants in Africa and design changes every month? | 70 |  |

# Self Test Questions

1. Describe the major components in the “Grammar of Design” concept. (Section 2)
2. What is a concept map? Draw one.(Section 3)
3. What is an activity cycle diagram? Draw one. (Section 4)
4. Describe the main elements of the Human Factors Cycle; give an example (Section 5a)
5. Describe design with a control model; give an example (Section 5b)
6. Describe design with a communication model; give an example (Section 5c)
7. Describe a product life cycle; give an example and elaborate on one of the stages.(Section 6)
8. Develop a classroom game, similar to the paper airplane exercise to demonstrate various steps in a product life cycle from the STS viewpoint (Section 8)

**Socio-Technical System Design**

**STUDY UNIT 3**

# The Tavistock Studies

1. Traced back to the studies of Trist and Bamforth (1951) of the introduction of new technology into deep seam Welsh coalmines.
   1. The original, largely manual, methods involved teams of coal miners doing a broad spectrum of jobs
   2. The introduction of mechanical cutters resulted in job specialization and much less worker interaction
   3. The result was lower productivity and inflexible processes that were vulnerable to subsystem failures
   4. A compromise method reverted to team structure while still using contemporary technology; this resulted in improved productivity and worker satisfaction

# The convergence hypothesis

* 1. This hypothesis suggests that technology will dictate work organization
  2. The Tavistock Institute studies refuted this hypothesis and demonstrated clearly that new technology could and should be adaptable to different work structures
  3. Studies of SE Asia textiles (spinning and weaving) also concluded that the technology was amenable to different / traditional work cultures in different SE Asian countries, although Japanese owned companies were more prescriptive in their work structuring.

# Joint causation

1. Systems consist of technological, environmental, personnel and organizational subsystems that interact to satisfy the “voice of the customers” / customer requirements
   1. The external environment (physical, social, economic, political) is normally not changeable
      1. Introduction of advanced large scale farming methods in developing countries
      2. Advanced workplace safety practices may not be effective in countries with undeveloped regulatory framework
      3. Introduction of energy saving electric / hybrid vehicles before recharging infrastructure is developed
      4. Introduction of small, energy efficient vehicles into a country accustomed to “gas guzzlers”
   2. The other three subsystems (technological, personnel and organizational) must be designed to be resilient to changes in the external environment through contingency allowances to mitigate the adverse effects of variation in the external environment
2. **Edwards (SHEL) model of system failure – similar to / forerunner to the joint causation model.**
3. Elwyn Edwards described these subsystems graphically with his SHEL model
4. The “Software” in Edwards model referred to “organization” and not to the “software” with which we are now familiar
5. Hardware (plus software), Liveware, Operations (including management), Environment (including temporal and social factors)
6. 4Is - Interfaces, Interdependencies, Interactions, Interferences

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Now we must add Software

Management Regulation

**H**

Hardware

**S**

Organizationware (Software)

INTERACTIONS INTERFACES

E

Environment

People Training

**L**

Liveware

The Physical and ***Operational*** Context

* 1. Complexity and failures occur with the 4Is which are in turn affected by the design of the particular subsystem
* Interfaces, interactions, interference
* Pilots, ATC, investigators, passengers

Hardware

* Airplane, components

Software

* Control and communication systems
* Fly by wire
* Terrain, traffic, weather systems

Organizationware

* Regulation, management

Environment

* Weather, visibility, terrain, traffic

•

•

•

•

Note that there may be conflicting purposes

*List and describe in detail the failure modes*

SHEL Example – Airplane Accident

* Liveware

# Recognition of the roles of the technological, human and operational subsystems

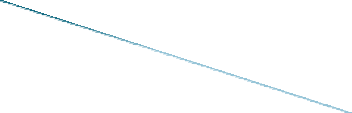
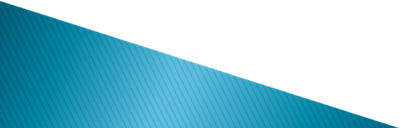
**P**

18

**B**

**E**

Since these early studies, various system analysis tools have been introduced that are broad in scope and address the Purpose and Scope of (Macro) Ergonomics.



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(C) Brian Peacock Ergonomics (BPE) Pte. Ltd. 7/29/2009

* Ease of Use
* Effectiveness
* Efficiency
* Safety
* Security
* Satisfaction

**E3 S3**

*Often there will be TRADEOFFS*

**Satisfaction** – All users of the system should be satisfied

with their experience and be motivated to continue to use the system

•

E3S3

* **Effectiveness** – The product or service meets customer quality expectations
* **Efficiency** – Productivity – optimal use of resources (people, money, materials, equipment, energy etc.)
* **Ease of Use** – Human interaction with the product or service should be convenient, comfortable and error free
* **Safety** – The system (product, service) should not fail and cause harm to the user, associated hardware, the environment or the organization.
* **Security** – The system should be resilient to malicious or accidental interference by third parties.
  1. Macroergonomics has three main components – management commitment, employee participation and attention to micro ergonomics
     1. Management commitment – if top management does not actively buy in to the challenges and opportunities that Macroergonomics brings then there will be no improvement in the outcomes
     2. Employee participation – if employees do not participate in system design and decision making then valuable information will be lost and gains will be minimal.
        1. Note that this contrasts strongly with the scientific management philosophy promoted by Taylor.
        2. Note also that employees may not have detailed knowledge of the technologies that are introduced but they will have considerable knowledge of their interactions with these technologies
     3. All opportunities for micro ergonomics analysis and intervention
        1. Human physical and cognitive capabilities and limitations
        2. Human social needs
        3. Equipment and process interfaces
        4. Environment and work context
        5. Temporal demands on performance
        6. Job, task and organizational structures, processes and outcomes.
     4. Case studies–
        1. the joint UAW / GM manufacturing ergonomics process
        2. The OSHA meatpacking guidelines and proposed ergonomics standard

# Simple descriptive tools for system, process and task analysis

1. E3S3 – common system failure modes
   1. Identify the type of failure and the tradeoffs among the different outcomes
2. Analyze the 4 Is –Interfaces, Interactions, Interdependencies and Interferences with regard to the various subsystems – Human, Hardware (and software),

Organizationware and Environment

1. Address the 5 Ws and a How - Who (By whom and to whom), What, When,

Where and How

* 1. When a system fails ask all these questions in order to be sure that all aspects of the failure are covered

1. Ask Why? at least 5 times for each of the above categorizations to identify a system failure root cause
2. Apply these tools both reactively and proactively in design

Because the road was icy

Why did the car crash?

*Apply 5 Ws, FMEA, SHEL,*

*HFACS with the 5 Whys*

Because the public require 24/7 protection

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Because the driver was asleep

Because the brakes failed

5 Whys Example

# Failure Modes and Effects Analysis

1. This is a semi quantitative process that is used for accident / incident analysis and during the system design process
   1. It can be used qualitatively but more advanced applications make use of quantitative data on historical failures to estimate failure probability and outcome severity.
   2. This analysis tool can be used to address the various subsystems in Socio Technical System Design – Personnel, Hardware, Organization, Environment and their Interfaces, Interactions, Interferences and Interdependencies

System House Lighting

Subsystem - Switch

FMEA Chart

Analyst - Me Date – 10/25/06

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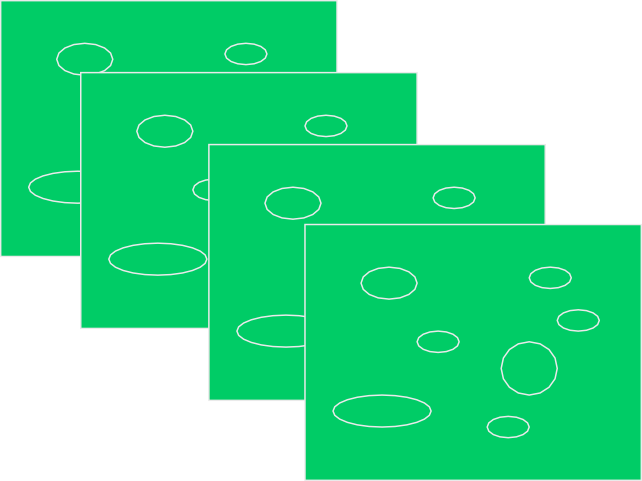
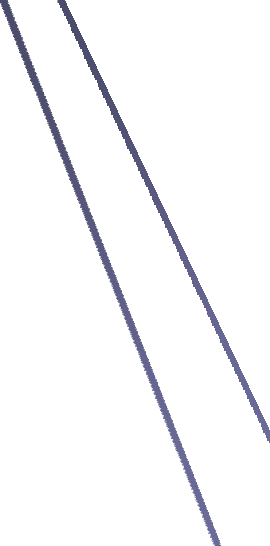
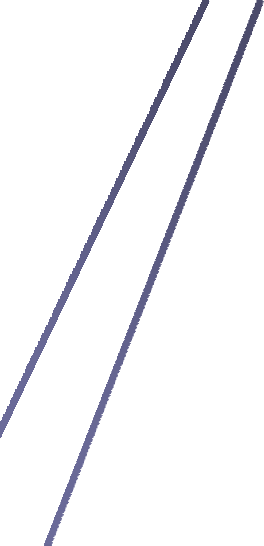
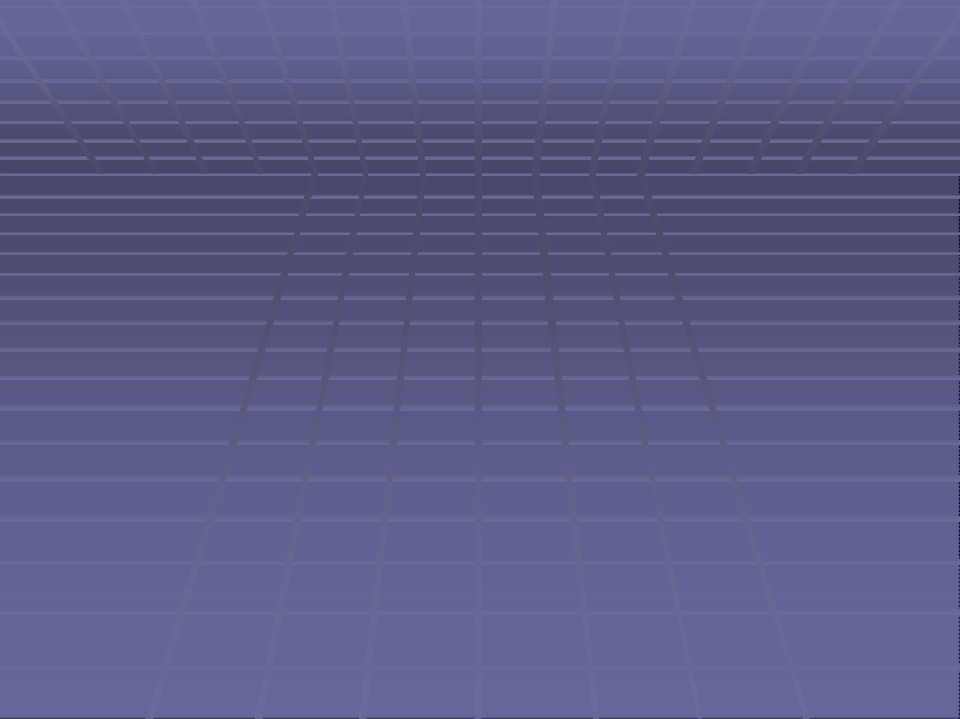
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|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Component** | **Failure Mode** | **Effects on other Components** | **Effects on System**  **(Worst case)** | **Hazard Probability** | **Outcome Severity** | **Risk Assessment Code** | **Comments** |
| **Wiring** | Short | Burn | House fire | 10-5 | Major | 2 | No fire alarms, sprinklers |
| **Cover** | Crack | Minimal | Minimal | 10-5 | Negligibl e | 4 | Buy a new one |
| **Screws** | Loose | Minimal | Minimal | 10-5 | Negligibl e | 4 | Tighten |
| **Contacts** | Broken | Open circuit | Loss of lights | 10-5 | Moderat e | 3 | No flashlight |
|  |  |  |  |  |  |  |  |

# Reason’s Swiss Cheese Model and HFAC

Two other similar models of system design and failure that can be applied to Socio Technical System Design and system failure

* 1. Reason’s Swiss Cheese Model
     1. This model suggests that system failures occur due to a successive failure of unsafe acts, preconditions, supervision and the organization; it is possible to prevent the accident by addressing any of these components
     2. A Top Down – Bottom up approach with management commitment and employee participation will be the most effective preventive strategy
     3. The model may be adapted to address failure modes of any aspect of a Socio Technical System



Swiss Cheese Model

*Accidents are*

**Preconditions**

*sequence / hierarchy of failure pathways*

**Unsafe Acts**

***Reason***

11/9/2009

BP ARTEX

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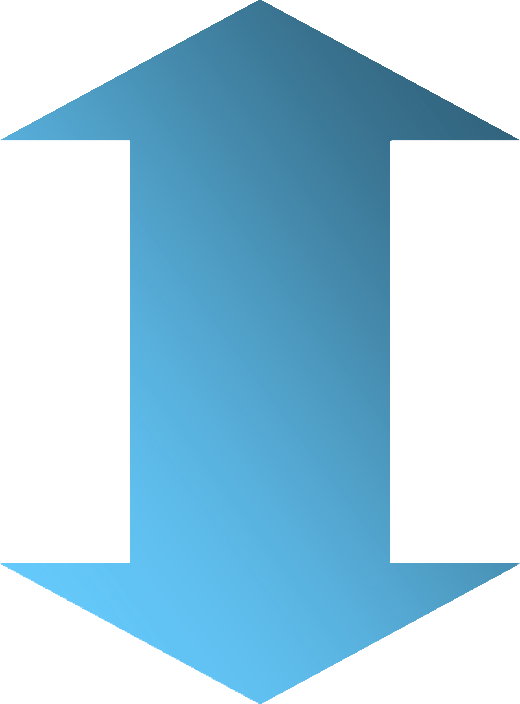
The “base event”

*caused by a*

**Supervision**

**Organization**

* 1. HFACS (Human Factors Analysis and Classification System)
     1. This approach to system and accident analysis was developed over the past 10 years, based on Reason’s Swiss Cheese model mainly for application in the aviation industry, but it can be applied, with small modification to the detailed questions to any Socio Technical System
     2. The model addresses
        1. The unsafe act itself – was it an accidental / occasional lapse or an habitual violation of the procedures
        2. The preconditions for the unsafe act – human, technological, organizational, environmental
        3. Supervision – Did the supervisory chain address habitual unsafe practices or initiate unsafe work
        4. Organizational influences – Does the organizational leadership stress a safety climate with safety processes and training throughout the organization
     3. See Charlotte, North Carolina crash analysis handout



**Organizational Process**

**Organizational Climate**

**Resource Management**

**Supervisory Violations**

**Failure to Correct Problem**

**Planned Inappropriate Operations**

**Inadequate Supervision**

**Personal**

**Crew Resource Management**

**Physical / Mental Limitations**

**Adverse Physiological States**

**Adverse Mental States**

**Technological**

**Physical**

**Personnel**

**Condition of Operators**

**Environmental**

Exceptional

Routine

Perceptual Errors

Skill based Errors Decision Errors

Violations

Errors

**Organizational Influences**

**Unsafe Supervision**

**Preconditions**

Unsafe Acts

# Handouts

11/9/2009

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Accident Investigation - Brian Peacock

1. 4s, 5s and 6s
2. FMEA
3. HFACS



**READ:**

*Chapter 2 – Macro Ergonomics Theory*

# Case Study – Data processing (Electricity company)

1. System and environmental scan
   1. 1972 introduction of Help Desk for UK Midlands Electricity Distribution Company
   2. “Fast Random Access Inquiry Devices”
   3. Dealt with service start up / discontinuation, billing, service and repairs
   4. No GUIs – just list and codes
   5. Hand held phones
   6. Many errors and customer complaints
      1. About the problem
      2. About the help desk
   7. Long wait times, very variable service times
2. Analysis
   1. Survey and interviews
   2. Errors mainly due to software bugs, poorly designed interface, absence of error recovery processes and operator unfamiliarity with system and interface
      1. In particular supervisors lagged the call center operators in understanding the vageries of the new system
   3. Frequent users were effective and efficient and had less errors than occasional users, but there were many occasional users
3. Solutions
   1. Selection, training,
   2. Data capture on calls to provide statistical evidence of failure modes
   3. Isolate and repair the software bugs
   4. Improved interface medium term
   5. Provide head sets
   6. Rotate operators and supervisors around other tasks to get broader system knowledge

**EXERCISE:**



1. Apartment complex design and management
2. Apply Socio technical system analysis of an apartment complex
   1. Use concept mapping
   2. Describe / sketch physical layouts (structures)
   3. List / describe hardware (structures)– apartment structure, gas, water, sewer, electricity, cable, doors, elevators, stairways, surrounds, transport services, parking, playgrounds, swimming pool etc
   4. Describe users - owners, tenants, managers, maintenance, security
   5. Describe processes – purchase / rental, access / security, maintenance, emergencies
   6. Identify potential problems and positive experiences (outcomes, E3S3)
   7. Develop data collection processes – surveys, incident reports etc
3. Recommend changes (re-design) to structures and processes
   1. Address people (training, information support), hardware (costly), processes ( less costly) opportunities
   2. Consider environment / context (unchangeable issues)
   3. Institute continuous improvement process
      1. Suggestion plan
      2. Periodic inspections
      3. Regular management / tenant meetings
      4. Notice board / electronic complex communications

# Self Test Questions

1. Describe the original STS coalmining studies (1)
2. Describe the purposes of system design; give examples (5)
3. Describe the components of the SHEL model; give examples (4)
4. Describe the 5 Whys analytic process; give an example (6)
5. Describe Failure Modes and Effects Analysis; give an example (7)
6. Describe Reason’s Swiss Cheese model of system failure; give an example (8)
7. Describe the major components of HFACS; give an example (9)
8. Draw a concept map to describe the factors to be considered in the design of an apartment complex (13)

**Socio-Technical System Design**

**STUDY UNIT 4**

# Macroergonomics methods / Participatory ergonomics (p30)

1. Quality of work life programs
   1. Companywide programs involving broad departmental representation to address work content and organization, quality, safety, facilities (cafeteria, fitness, parking etc) also self help
2. Self directed work teams
   1. Semi autonomous production teams with free range to assign work among themselves
   2. Contribute also to product design, process, quality, productivity and safety issues
3. Cross functional teams
   1. Usually made up of representatives from specialist departments focused on issues (usability, cost, design) related to a particular product
   2. May also address safety
   3. May be set up as ad hoc, limited time teams, to address particular problems such as poor supplier quality, in process damage
4. Product development teams
   1. Developed during design process with representatives from marketing, design, engineering, manufacturing, production and human factors / ergonomics to address the needs of all constituencies during product development
      1. May include employee representatives from the manufacturing plant
   2. Also called Design for Manufacturing / Design for Assembly teams
5. Quality circles – flexible, often problem oriented, teams
   1. Introduced in the Japanese automobile industry to address the real and perceived quality problems with Japanese products in the early 1980s
   2. Usually cross functional teams, including line workers
   3. Had an enormous impact on vehicle quality
   4. These were management initiated team activities with employee involvement
6. Participation
   1. Describes involvement of production workers in “extra production” activity
      1. Participation in manufacturing / production operations / process design
      2. Participation in product design
      3. Participation in training
      4. Participation in quality and productivity discussions and interventions
      5. Participation in safety programs
      6. May be top down or bottom up
         1. Management designed and managed teams
         2. Teams based on union contracts, jointly managed by union and management
7. Mechanisms of participation
   1. Standing committees – related to routine issues or focused work groups to address problems
   2. Ad hoc, problem focused teams
   3. Visual controls
      1. Display of outcome data related to quality, productivity, safety
      2. Andon chord – the ability and responsibility of any worker to stop the line if any form of problem arises, such as with component quality, safety, inappropriate behavior

# STS Investigation Methods (p40)

* 1. Consider data accuracy (no bias) and reliability
  2. Field studies (p41)
     1. Realism – studying actual people at work has considerable face validity
     2. Lack of control of context and independent variables
     3. Observer effect – the process of observation may affect how the operator does his job
        1. Case study on end of press line staffing
           1. Led to $2B strike!
  3. Field experiments
     1. Greater control than observational studies – applies formal experimental design methods – control of independent and concomitant variables
     2. Very difficult to implement in practice
     3. Realism – retains the face validity of field observation studies, however there may be bias due to subject / operator favoring one or other of the experimental manipulations
        1. An example would be parallel departments / groups with different processes / equipment but same objectives
        2. Another example would be the experimental introduction of job rotation or manual materials handling aids (hoists, arms, Cobots etc.)
     4. Greater observer effect – may influence behavior and attitudes
        1. Hawthorne effect?
        2. Example - Electronic data processing “pilot team”
           1. Medicare data processing / claims handling
           2. Dissatisfaction with computer system reliability
           3. Keystroke monitoring for productivity
           4. General productivity, quality and morale problems
           5. Work tasks subdivided and simplified
           6. Work layout – like a classroom with supervisor at the front
           7. Cross functional team implementation

Cross training period was needed

Office rearrangement necessary

* + - * 1. Considerable support from the highly selected pilot team members
        2. Some job specialization remained by choice of the team
        3. Attention to micro ergonomics issues – carpeting, computer system upgrades
        4. Much better within team communication to deal with problem cases
        5. Great improvements in productivity, quality and job satisfaction
        6. Pressure to expand the concept before the trial period was over
    1. Example – early introduction of in vehicle navigation systems
       1. Technology push, marketing and management support
       2. HF distraction concerns – conflict with management
       3. Contemporary technology with better interface and functionality contains distraction warnings
       4. Similar to contemporary cell phone / texting issues while driving
          1. Micro ergonomics issues of driver spare mental capacity
          2. Hands free red herring
  1. Survey methods (p42)
     1. Questionnaires
        1. Limit length to maintain attention of the subject
        2. Focus on particular issues, don’t be too broad
        3. Sometimes implement more general periodic QWL surveys e.g. every six months (system satisfaction scan)
        4. Unambiguous response selection
        5. Allow space for explanatory comments
        6. Population sampling – many dangers of bias if surveys are not designed properly
        7. Response bias – for example only people favorable to the subject may respond
        8. Non punitive / anonymous incident reporting
           1. Widely used in US aviation industry to address safety violations
           2. Sometimes mistrust in use of the information results in under reporting
  2. Interviews (p44)
     1. Structured questioning – the investigator must have a template or pre arranged set of questions
     2. The respondent must be assured of confidentiality / anonymity and be allowed to not answer particular questions or discontinue the interview at any time
     3. Interviewer bias may creep in depending on interviewer style
        1. Example of the relative success rates of different interviewers in a Hong Kong biomedical survey
  3. Focus groups (p45)
     1. Mediator training is needed to assure
        1. Equal opportunity for all the participants
        2. That the conversation does not wander off subject
        3. That individuals do not use the platform to further their own agendas
     2. Not more than ten participants per group, otherwise the discussions become unwieldy and difficult to manage
     3. Examples
        1. Design of remote entry systems for cars
           1. Brainstorming suggested very many applications –car “brains” in a card
           2. Limited feature remote entry system introduced
        2. Use of advanced synthetic terrain display technology in aviation
           1. Considerable technology push
           2. Naïve realism possibilities
           3. Need for “off” mode unless needed (strong focus group message)
           4. Small incremental improvement over simpler systems supported by formal laboratory investigations
        3. Head up displays in cars
           1. General engineering push for high content displays
           2. Focus group support for high content displays
           3. Laboratory experiments demonstrated considerable cognitive capture / distraction effects
           4. Low content implemented in upscale vehicles
           5. Market did not respond positively
  4. Laboratory simulations (p45)
     1. Allow role playing by group participants to address particular operational or social issues
        1. They can be fun and productive / informative
        2. They can also be counterproductive if not well controlled
        3. Example - Sexual harassment sensitivity training for managers and employees
     2. Simulations may also involve physical mockups of product, equipment or work place of interest
        1. Example Styrofoam mock ups of manufacturing work places / equipment
        2. Bamboo mock ups of Hong Kong Mass Transit Railway passenger compartment and ticket turnstiles to address passenger movement issues
     3. Table top simulations using scaled pieces can be used interactively to address workplace layout issues
     4. Interactive simulation software, especially with animation, may be used to explore alternative resource allocation strategies, procedures and layouts
        1. Example - discrete event simulation studies of emergency evacuation from transport category aircraft (see Handout)
           1. Focused attention on blockages, layout, passenger behaviors, cabin crew training and behaviors
           2. Integrated with staged physical simulations / demonstrations

# Work system Structures

1. Woodward (1965) studied 100 large companies to detect reasons for relative success
   1. Variable managerial levels (2 – 12)
   2. Variable span of control (2 – 12 at top and up to 90 at first supervisory level
   3. Effect of technology on organizational structures
      1. Unit (craft work), batch, mass (automobile manufacturers) or process (e.g. gas and oil) production
   4. Complexity brought vertical differentiation
      1. Increased number of administrative staff
         1. Successful companies had moderate vertical differentiation
            1. Unit – 3, mass 4, process – 6 levels
      2. Ratio of administrative to production staff increased with complexity
   5. Indicators of success
      1. Unit companies, low complexity, low staff to production ratio, small span of control for first line supervisors
      2. Mass production – narrowly defined jobs, high formalization (standardized jobs) and centralization (decision makers at highest levels

– little bottom up communication)

* + 1. Process production – high vertical differentiation (many levels) supervisors had wide spans of control, relatively low formalization and centralization – (decision making resident in lower levels)
  1. Complexity often solved by formalization and high vertical differentiation / hierarchies
     1. Spatial / Geographical separation increased need for development of parallel committee structures which led to
        1. Competition between line management and committees
        2. Communications difficulties, especially bottom up communication

1. Technology centered production (automation) led to high vertical differentiation – hierarchies and associated
   1. Productivity and quality gains
   2. Increased focus on maintenance
   3. Workforce retraining / redundancies
2. Machine Bureaucracies (p60)
   1. Usually very prescriptive work
      1. Inflexible
   2. Taylorism
      1. Work simplification for quality – very short job cycles – easily learned
      2. Management’s responsibility became one of training, monitoring and problem solving
      3. Line workers trained to – “experienced worker standard” – for rate setting
      4. Line balance – equal workload to keep the production line running smoothly
      5. Supervision became impersonal - management must be “scientific and objective”
   3. Industrial Engineering
      1. Development of standard times
         1. Using systems such as MTM, Work Factor etc
      2. Modified workplace layout to reduce non value added movements of people and materials
         1. Tools were hung on balancers close to the job
         2. Materials / components baskets were brought as close to the line as possible
         3. Conveyors moved the product through the assembly process
      3. Job specialization became the norm with job choice being based on seniority in unionized organizations
      4. The effect of IE methods were increased and more predictable production rates, and more accurate product costing
         1. Later greater refinements were made with lean and agile manufacturing, work cell development and processes such as 6 sigma based on statistical process control
      5. From the mid 1980s ergonomics was introduced to reduce the adverse effects of repetitive work
         1. Ergonomics contributions included work place arrangement to reduce awkward postures and movements, job aids to reduce forces and job rotation to reduce repetition
      6. Centralization became the norm in mass production industries with top down decision making (“votes equals opinion times salary”)
      7. Formalization - increased levels of standardized work often leading to very short cycle times – just a few seconds in component manufacturing
         1. Example – contemporary meat packing
3. Knowledge centered organizations or Professional bureaucracies (p62) have greater horizontal differentiation and are divided up into technology centers
4. Usually highly trained individuals – college degrees in engineering or technology
5. Examples of professional bureaucracies include Hospitals, Universities,

Research organizations, especially within government

1. Less / minimal top down control, management deals with policy and resource allocation, professionals are the technical decision makers
2. Sometimes professionals become difficult to manage due to their confidence in their own value to the organization
3. Adhocracies (p63)
   1. Matrix organizations
      1. Seen as a method to improve flexibility with new programs
      2. Organization divided into technology and program centers
      3. Technology centers supply necessary skills to programs
         1. E.g. robotics, fastening, product engineering, manufacturing, industrial engineering, materials, human factors, paint, welding etc.
      4. Programs have majority of funding
      5. Technology centers retain some funding for R&D
      6. Employees have the problem of two bosses – their home technology center and the program to which they are assigned
      7. Managers have the problem that employees may not balance their loyalty equally
   2. Product development teams introduced during design process with representatives from marketing, design, engineering, manufacturing, production to address the needs of all constituencies during product development
   3. Also called Design for Manufacturing / Design for Assembly teams
4. Degree of skill / professionalism (p51)
   1. Work can be described according to the following general categories
      1. Production line – short cycle work, minimal training
         1. Automobile assembly, textiles
      2. Craft / skilled trades work, longer training, mainly rule based
         1. Maintenance, plumber, electrician, carpenter etc
      3. Creative work, skill based, but with experimentation
         1. Arts and crafts, acting, music
      4. Knowledge work – deductive reasoning, problem solving
         1. Medicine, engineering, law
      5. Investigative work – inductive reasoning, research
         1. University research
5. **Demographic factors** have considerable effect on the type of work that an individual performs
6. Age
   1. Child labor in developing countries with minimal education systems, routine work
   2. Work experience produces efficiency, but less versatility
   3. Work pace diminishes with age
   4. Increasing problem in developed countries – graying of the workforce
7. Sex
   1. Traditional roles / jobs – e.g. textiles, agriculture, homemaking

(1) Varies with country

* 1. Move into management / glass ceiling – females generally lag their male counterparts in both mechanical and professional bureaucracies
  2. Diversity, equal employment opportunity legislation is being pursued aggressively in the US and Western Europe to level the hiring and salaries of females and minorities
     1. Affirmative action programs
     2. Quota programs

1. Ethnic origin
   1. Immigrant workers
      1. A reality in most industrialized countries
      2. Cultural and language differences sometimes alienate the community
      3. Training / language challenges lead to immigrant workers being offered only menial and lower paid jobs
      4. Development of ethnic “ghettos”
      5. Turnover – workers return to their home countries
      6. Line “unbalance” to bring new workers up to speed is applied as a pragmatic process in some short cycle assembly jobs
      7. Developing countries with ready available trainable workforce from rural regions
         1. China, South East Asia, Mexico
      8. Lower paid jobs
         1. Assembly, service operations, cleaning, agriculture

# Environmental factors

* 1. Socioeconomic
     1. Companies locate new plants close to the available / experienced workforce
        1. Automobile industry in US
        2. Greenfield plants
     2. New plants may be launched where there is an abundance of trained or trainable labor
        1. Japanese textiles, electronics and plastic plant expanded throughout SE Asia
        2. Japanese automobile manufacturing plants spread to the US
        3. US and European components manufacturing spread to Mexico, Eastern Europe
        4. US and European IT facilities moved to India
        5. US and European manufacturing activities moved to China and Korea
        6. Now China, India and Korea dominate these industries and build plants in Western Europe and the US to be closer to the market
     3. Problems arise for communities following the undulations of the economy
        1. Whole towns may suffer if they rely on a single company that closes
           1. Flint, Pontiac, Nummi
  2. Educational
     1. Industry relies on the educational system to provide sufficient numbers of professional and technical job candidates
     2. Establishment of local R&D centers around universities and centers of expertise
        1. Silicon Valley in California
        2. Research Triangle in N Carolina
        3. I75 corridor in Michigan
  3. Political
     1. Unions
        1. Originally focused on health and safety and working conditions
        2. Now very much involved in salary negotiations
        3. Also unions argue strongly for participation in all levels of the organization
     2. Seniority is the main mechanism for job choice and wages
        1. “Incompetence is no reason for dismissal” – Peter Sellers movie about a Japanese car plant in the US
        2. May interfere with team structure, job rotation and job enlargement
     3. National and International work standards and regulations
        1. ILO – International Labor Office promulgates employment and safety standards
           1. ILO is a strong proponent of participation in the workplace
        2. ANSI – American National Standards Institution promulgates national product and manufacturing standards
        3. Lesser standards in developing countries
  4. Cultural
     1. Nationality / ethnic differences affect organizational processes
     2. Management styles
        1. Autocratic – top down, rule based
        2. Collaborative / participative style either top down or bottom up
  5. Legal / Policy
     1. National laws and standards vary considerably from country to country
        1. Safety laws are generally less stringent in developing countries
           1. Mortality and morbidity statistics reflect these differences
        2. Diversity – equal access and employment opportunity is a major issue in the industrially developed countries
           1. Addresses discrimination on the basis of sex, age, ethnicity, sexual orientation, disability etc.



**EXERCISE:**

1. Social Network
   1. Assess a common social networks such as Facebook, Linkedin, Myspace, Friends reunited, Bebo etc as a Socio Technical System using the 6Us
   2. Address software and hardware design interface issues
   3. Address spectrum of users / usability
   4. Address privacy / safety / security issues
   5. Use 6Us and 5 Whys analysis processes

# Case Study

1. ACCESS Car (See handout)
   1. Transportation for the elderly
   2. Physical access
      1. Seats, seat belts, step over, storage, controls
   3. Informational access
      1. Instrument cluster, navigation, lights, entertainment, communication
   4. Social / operational access
      1. Neighborhood car, Emergency communication system, lease and rentals
      2. Agent- broker system
         1. “Let me tell you about my grandchildren”

# 6 Us (and 2Ms)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Product or Process Description** | **Why? Why?**  **Why?** | **Product or Process Analysis** | **Why? Why?**  **Why?** |
| **Utility** | Why is the product or  process useful? |  | Why should the  product be improved? |  |
| **Usage** | In what way will the product or process be  used |  | In what context will the product be used? |  |
| **Utilization** | How often and by how many people will the product or process be  used? |  | What are the probability and frequency of failure? |  |
| **User** | Who is the intended user? |  | How can the intended user be selected or trained to use the  product or process? |  |
| **Misuser** | Who is the expected misuser? |  | What kinds of users will be associated with  these failure modes? |  |
| **Usability** | How easy is it to use the product or process |  | How could the product or process be changed  to make it easier to use? |  |
| **Misuse** | How easy is it to misuse the product or process |  | How could the product or process be changed to prevent and mitigate  the effects of misuse? |  |
| **User Error** | What kinds of failure modes can be  predicted? |  | What are the consequences of  failure? |  |
|  |  |  |  |  |

# Self Test Questions

* 1. Describe, with examples, 5 forms of participation design. (1)
  2. Describe 4 kinds of STS investigation methods (2)
  3. Describe Woodward’s categorization of work systems; give examples (3)
  4. Describe a Machine Bureaucracy; give an example (3c)
  5. Describe a Professional Bureaucracy; give an example. (3d)
  6. Describe a Matrix organization; give an example.(3e)
  7. Describe some demographic factors that should be addressed in Socio Technical System Design (4)
  8. Describe some “environmental” factors that should be considered in Socio Technical System design (5)
  9. What factors should be considered in designing a transportation system for the elderly? (8)
  10. Describe the 6Us method of assessing system usability (9)
  11. What factors should be considered in designing an Internet based Social Network for ergonomists? (9)

**Socio-Technical System Design**

**STUDY UNIT 5**

# Introduction

This chapter describes the step by step process of socio technical system analysis, design, implementation and evaluation

# Review of systems theory (see Study unit 2)

* 1. Systems
  2. Processes
  3. Requirements
  4. Specifications
  5. Verification
  6. Validation
  7. Life cycle
  8. Concurrent engineering
  9. Purposes / outcomes

# Work types (see Woodward in Study Unit 4)

* 1. Process control
     1. Monitoring tasks require system knowledge, vigilance and sustained attention to detect discrepancies / variances in process behavior
     2. Must have knowledge, rules and skills to respond to emergencies
        1. Rules address immediate tasks such as “remove the power source”
        2. Skills require experience and practice
           1. May be obtained through simulator training
        3. Typical tasks are in petro chemical processing and aviation
  2. Craft work
     1. Work such as skilled trades (plumber, electrician, carpenter, farmer, forester, model maker, artist) where each job is somewhat unique and requires adaptability of the person based on fundamental training / skill and broad contextual experience
  3. Job shops
     1. Low throughput or one off production facilities staffed by team of specialists
     2. Varied level of job skill breadth and system flexibility
     3. Typical jobs include construction and large equipment manufacturing
     4. Also found in repair facilities
  4. Short cycle / production line work
     1. Typical production line work – automobiles, computers, toys, textiles, food processing – with cycles ranging from a few seconds to a few minutes.
        1. Task choice by seniority
        2. Job rotation and enlargement opportunities to reduce physical stress, create a more flexible workforce and increase understanding of the larger product picture
     2. Also found in routine tasks like Air Traffic Control, Retail Check out and “Help Desks”, or call centers
        1. Job cycle may last a few seconds to a few minutes
        2. May require skill and rule based decision making

# Job design methods

* 1. Job rotation
     1. Purpose is to relieve physical and cognitive stress, and to increase flexibility of the workforce by broadening the skill sets
     2. Applied in high frequency assembly (disassembly) work and customer service jobs
     3. Operator rotates round five or six tasks every hour or so
     4. Sometimes rotation may be quicker – every few minutes or slower – every few days.
     5. See handout on “The Case for Job Rotation”
  2. Horizontal job enlargement
     1. Increasing the duration of a production job cycle by increasing the number of elements
        1. Cycle time may be 5 minutes to an hour
        2. Each operator takes a production / service unit through a series of work stations / operations
        3. Increases knowledge / flexibility of the work force
        4. Reduces the repetition component of physical and cognitive stress
  3. Vertical job enlargement
     1. Allows operators to participate in tasks other than the direct production

/ service task such as:

* + - 1. Design of tasks, including workplace layout, equipment, tools, methods and product / component design
      2. Assignments among the work group, including rotations and individual assignments
      3. Quality and productivity –“ there is always a better way”; line operators have a unique insight into the product and process
      4. Safety – ad hoc and statistical evidence may be applied to the reduction or severity of acute and cumulative morbidity
  1. Work cells
     1. A collection of machines, operations and operators around a small area in contrast to the linear production line
        1. Purpose is to improve productivity by reducing the distance and time of product and component handling, and by reducing the in process storage of products
        2. Also quality improvements may be achieved by giving individual or groups of workers responsibility for more machines / operations
        3. Work cells may be staffed by individuals or groups
        4. Similar method and time analyses and standards are applied to those used in production line work

# Socio Technical Systems (STS) Analysis

* 1. Vision, mission, principles and policies (p69)
     1. A Socio Technical Systems analysis should begin with a scan of the high level vision, mission, principles and policies of the organization
     2. This scan can identify gaps in the system design such as the organization’s concern for employee remuneration, health, safety and well being or for operator induced continuous improvement (Kanzei Engineering)
     3. The scan will also identify the external environment including market, labor, unions, plant locations, suppliers, raw materials, applicable regulations
        1. Concept mapping is a good tool for this analysis
     4. Policies such as participatory practices should be identified in this high level scan
  2. Environmental scan
     1. Descriptions of the physical, temporal, geographical, social, economic, market, competition, regulatory and demographic context in which the organization exists
     2. Note that this context is usually unchangeable so the system design must adapt to both benefit from the environmental context and withstand adverse effects of the context.
        1. Examples include developing organizations close to resources (people, raw materials) and markets
        2. Another example might be the avoidance of potentially catastrophic environmental influences - severe weather, earthquakes, political unrest
        3. Japanese and European car makers develop plants in the US – close to the markets to reduce transportation costs and to give the impression that the vehicle is “made in the USA” despite the fact

that many components come from overseas and the revenue goes overseas.

* 1. Organization scan (p70)
     1. This is a more detailed scan of the organization subsystems
     2. Descriptions of the products / services, manufacturing processes, quality management
     3. Description of the organization structure – divisions, departments, interdependencies, technical and administrative support subsystems
     4. Descriptions of the personnel subsystem - hierarchies, supervision, span of control, work assignments and practices
     5. Description of the statistical subsystem measuring process behavior and outcomes – materials, products, equipment and tooling, quality, safety, costs
     6. Description of the environmental subsystem (p71)– suppliers and customers, locations, physical environment, transportation, community, demographics, regulations, etc.
  2. System and process analysis
     1. Technology (Hardware and software) – a detailed description of the technology and its functions
     2. Liveware – a detailed description of the particular work assignments, job design practices, assignments , selection, training
     3. Organizationware – a detailed description of the flow of materials, products, people and information through and around the organization
        1. Use activity cycle diagrams
        2. Also address shift work and job rotation issues
     4. Interactions, Interdependencies, Interfaces and Interruptions – a description of the relationships among technological, personnel, environmental and organization subsystems
  3. Product / service scan
     1. Product quality
        1. Analysis of the incoming materials quality and outgoing product quality and the quality audits from different parts of the organization
     2. Productivity
        1. Resource ( equipment, people, power, money) evaluation overall and in different departments
  4. Safety and Security scan
     1. Injury / illness statistics overall and by department
     2. Survey of hazardous operations using FMEA
     3. Evaluation of risk of materials, product, tools and information theft
  5. Work satisfaction scan
     1. Using, interviews, focus groups, employee surveys to detect perceived and actual shortcoming of the technological, personnel, organizational and environmental subsystems

# Develop company structure / process / outcome analyses

* 1. Specify organization structural design (p74)
     1. Describe department hierarchies, span of control, geographical separation, technology, personnel, environments / contexts
     2. Use concept mapping
  2. Define process flows and outcomes (p75)
     1. Describe interdependencies, interfaces, interactions, interferences
     2. Use activity cycle diagrams to show resource allocation and process branching logic
     3. Establish realistic targets and goals regarding outcomes (p78)
        1. Use evaluation matrix (see below)
  3. Describe micro process inputs/resources, process logic and outcomes
     1. Use activity cycle diagrams
  4. Collect and analyze variance data (p76)
     1. Use evaluation matrices for snapshot
     2. Develop control charts for temporal trends in outcome variance data
     3. Distinguish special and common causes of variances from targets/ goals
  5. Profile analysis using common currency
     1. Develop metrics for all operations (inputs / resources, outcomes)
        1. Use E3S3 – effectiveness (quality), efficiency (productivity / resource utilization), ease of use, safety, security, satisfaction)
        2. Sample metrics – reject rate, throughput, operator ratings, injury rate, security reports, worker satisfaction ratings
     2. Convert metrics to (pre – weighted) common currency scale using consensus process

Evaluation

* Verification
* Validation
* Sensitivity

Rule Implementation



History

Predictions

Outcome Target

Data

Design Rule

Policy Science

Experience

Consensus:

* HF Experts
* Engineers
* Managers
* Employees
* Customers

Consensus

The mapping – our challenge

Outcome

Requirements

Design Specifications

(Engineerable measures)

Common

Currency

Requirements and Specifications

Common Currency

* Links risk and importance level.
  + Safety, task performance, efficiency etc.
* Sufficient resolution.

– 100, 10, 7, 5, 3 point scale?

* + Yes / No
* Covers the area of interest.

Ideal Region

*Engineering Specifications*

*Process*

*Outcome Requirements*

Region of full agreement

Decision Ranges and Thresholds

* + 1. Plot results in evaluation matrix

**Region of Uncertainty and Interactions**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Outcome** | **Effectiveness** | **Efficiency** | **Ease of Use** | **Safety** | **Information** | **Employee** |  |
| **Life Cycle Stage** |  | **Quality** | **Productivity** | **Complexity** | **Health** | **Security** | **Satisfaction** | **Average** |
| **Design** | **Product** | **10** | **0** | **3** | **4** | **0** | **6** | **3.8** |
|  | **Manufacturing** | **5** | **10** | **1** | **7** | **2** | **0** | **4.2** |
| **Production** | **Component** | **2** | **1** | **5** | **8** | **1** | **7** | **4.0** |
|  | **Assembly** | **7** | **7** | **9** | **0** | **7** | **2** | **5.3** |
| **Distribution** |  | **3** | **10** | **9** | **5** | **9** | **0** | **6.0** |
| **Maintenance** |  | **4** | **10** | **3** | **9** | **2** | **2** | **5.0** |
|  | **Average** | **5.2** | **6.3** | **5.0** | **5.5** | **3.5** | **2.8** | **4.7** |

**(i) Example organization evaluation matrix**

**Outcome Summary Matrix**

* + 1. Enables all stakeholders (management, employees, customers, shareholders) to view the “forest as well as the trees”
    2. Score by COUNTING – number of reds, yellow, greens.
       1. Possible decision rule – 1 red or three yellows is a show stopper
    3. Note that more specific process stages and outcome metrics may be used
    4. Experience with similar analytical processes (Quality Function Deployment, ISO 9000) demonstrates the danger of too detailed analyses in that the analytic process can become cumbersome, time consuming and of diminishing utility.
       1. It is suggested that an upper limit for any evaluation matrix should be not greater than 10 x 10.

1. Index of organization performance
   1. Can be calculated using common currency and element weighting
   2. Can be the simple averages as shown above, given that the “weighting” was applied to each variable by consensus in the original process / outcome assessments
      1. Note that different constituencies will attempt to weight the different evaluation criteria differently, that is why the consensus process should be used in metric development
   3. Benchmarking with similar companies using comparable metrics is informative
2. The index of performance can be further assessed by a Risk / Consequence process in which each process failure mode score (high in the example) reflects the probability of failure and the consequence of this failure mode in terms of damage to people, equipment / technology, the environment and the organization is assessed using a similar consensus process or quantitative evidence where available. A typical Risk / Consequence matrix is shown below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 5 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 1 |  |  |  |  |  |
|  | 1 | 2 | 3 | 4 | 5 |

# Design

**Risk / Consequence Matrices**

Risk

Probability

**Outcome / Consequences**

* 1. Classical system design model (adapted from Singleton) (p74, 82)

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System Design

* + 1. Define mission, purpose, outcome targets

***Test and Evaluation***

Organizationware Design

Humanware Design

Software Design

Hardware Design

**Allocation of Functions to Systems and Subsystems**

Systems and Subsystems

Mission / Purpose Design Concept Design

Identification of Contexts / Environments

Separation of Functions and Processes

Continuous Improvement

**Interface Design**

* **Verification of specifications**
* **Validation of requirements**
  + 1. Develop alternative concept designs
    2. Evaluate context / environment of use
    3. Describe organizational context
    4. Define functions and processes(p82)
    5. Evaluate user population characteristics
    6. Evaluate failure modes / probabilities / consequences (FMEA)
    7. Allocate functions between people and equipment
       1. Human roles
          1. Refer to Fitts lists
          2. Should be designed to be stimulating and make good use of human capabilities
          3. Not “left over roles”
          4. Machine supervision
       2. Hardware / software roles
          1. Refer to Fitts lists
          2. Routine
          3. High force, high repetition
          4. Hostile environments for human activity
          5. High precision
    8. Develop subsystems
       1. Hardware
          1. Functions, Costs, reliability, service and maintenance
       2. Human
          1. Functions, Selection, Training, Assignment
          2. Develop job / task scope, enlargements, rotations, shift systems etc
    9. Develop metrics, collect and analyze data and develop visual controls using for Materials, Information, Production, Products addressing:
       1. E3S3
          1. Quality (Effectiveness)
          2. Productivity (Efficiency)
          3. Safety and Security
          4. Satisfaction, usability / ease of use
  1. Address system life cycle
     1. Product, process and production operations design
        1. Develop outcome targets (E3S3)
        2. Identify and rectify failure modes early in the design process
           1. Catch the big / product design fish early



**Sequential Evaluations**



Product Design

Process Design  

Production Design 

Operations

* + 1. Production operations
       1. Record and analyze outcome data
    2. Use, maintenance and disposal
       1. Identify and measure outcomes (E3S3) for each activity
       2. Analyze outcome data
       3. Identify failure modes using FMEA, 5Ws, 5 Whys etc
       4. Rectify product, manufacturing and production operations design and operations root causes
    3. Develop interventions regarding, production, manufacturing, product/ component, operator, organizational and environmental factors
       1. Assess cost benefit of interventions
    4. Implement redesigns

# Handouts

* 1. Measurement in manufacturing ergonomics



**READ:**

*Chapter 5 – Analysis and Design of Work System Process*

# Case Study 1 – Digital Library (p70)

* 1. Identify discrepancies / variances
     1. Identify relationships and root causes of variances
     2. Develop variance control matrix
     3. Identify human, technology, organization and environmental contributions to variances
  2. Identify inputs and sources– authors, reports, books, papers, lecture notes etc
  3. Carry out internal controls for content management
  4. Identify legal issues regarding ownership, copyright
  5. Address technology alternatives
     1. Hardware, software
     2. Indentify special skills needed for this technology
  6. Develop delivery medium
     1. Internet
     2. Web page design
     3. Access control
  7. Identify customers

# Case Study 2 – Automobile manufacturing

* 1. Construct concept map and annotated process flow diagram
  2. Product design for manufacturing, production, maintenance, use and disposal
     1. Use the 6Us analysis method
  3. Process scan
     1. Body
        1. Robotic welding – more consistent than manual
        2. Difficult welds left to operator
        3. Repetitive sanding to smooth welds
        4. Machine monitoring and maintenance – tip change etc.
     2. Paint
        1. Mainly robotic – more consistent than manual
           1. Difficult areas left to human operator
           2. Residual human tasks

Inspection

Repair

Cleaning

Machine maintenance

* + 1. Chassis and engine
       1. Mainly threaded fasteners
       2. Automatic torque control
       3. Often difficult access / orientations
          1. DFM / DFA opportunities
    2. General assembly
       1. Often push fasteners
          1. Exterior and interior trim, wiring bundles
    3. Machine paced work
       1. Andon chords – stop the line for problems
       2. Visual controls
  1. Shift work, Work related musculo skeletal disorders
  2. Environmental scan
     1. Economic
        1. High priced units
        2. Considerable external competition
     2. Political environment
        1. Highly regulated industry
        2. Unionized – UAW
        3. Free international market
     3. Organizational environment
        1. Very large company
        2. Vertically differentiated
        3. Multiple brand names
        4. Many component manufacturing and vehicle assembly plants worldwide
        5. Three major design and engineering facilities
        6. Matrix organization for engineering
        7. Dedicated design and marketing functions by brands.
     4. Social environment
        1. Plants often the major employer in the city
           1. Pontiac, Flint, Hamtramck
           2. Substantial hardship following plant closure
           3. Jobs bank – continued employment at reduced rate if laid off due to production cutbacks
  3. People scan
     1. Salaried and hourly
     2. Hourly workers represented by UAW
        1. Relatively good wage rates
        2. Production workers, maintenance and materials are the main occupations
        3. Job choice by seniority (from date of hire)
        4. Aging workforce
     3. Short cycle work – 40 seconds to 5 minutes
     4. Some plants have team structure with job rotation
     5. Shift work – flexibility depending on demand
  4. Work design scan (General Assembly)
     1. Awkward postures – under and inside vehicle compartments
     2. Threaded fasteners with torque reaction stress
     3. Push fasteners with posture, force and repetition stress, supported on balancers where convenient
     4. Heavy components / subassemblies may or may not use articulating arms or, more recently, cobots.
     5. Tuggers and fork lift trucks used for materials delivery
  5. Work related musculo skeletal disorders
     1. Upper limb tendinitis, carpal tunnel syndrome, back and shoulder injuries
     2. Reached epidemic proportions as push for productivity increases line rates
     3. Posture and force issues addressed by various ergonomics interventions
     4. Repetition issues addressed by work content negotiations and job rotation.
     5. Major medical management strategy
     6. Development of ergonomics teams in all plants
     7. Development of major proactive (DFM/DFA) program

# Self Test Questions



**EXERCISE – Training / Employment for Teenagers with developmental disorders**

1. View as a STS – people, technology, environment operations
2. Use concept mapping and activity cycle diagrams
3. Identify the persons needs
   1. Use International Classification of Function
   2. Personal care, transportation, educational / occupational skills, relationships, recreation, self esteem
4. Identify helpers – family, community, government / charities, centers, trained helpers
5. Identify facilities and special equipment
6. Develop model program
   1. Personnel skills and roles
   2. Facilities and equipment
   3. Transportation / logistics
   4. Operations
   5. Describe with examples
      1. Craft work (3b)
      2. Job shops (3c)
      3. Production lines (3d)
   6. Describe with examples
      1. Job rotation (4a)
      2. Horizontal job enlargement (4b)
      3. Vertical job enlargement (4c)
      4. Work cells(4d)
   7. Describe 5 stages of STS analysis (5)
   8. Describe the common currency method of company process analysis (6)
      1. Describe 5 steps in company process analysis (6, 8) What are the two major components of Risk analysis? (6g)
      2. Describe the classical system design model (7)
   9. Describe an example of process analysis from the automobile manufacturing industry (11)
   10. Describe an analysis of process analysis for the employment of teenagers with developmental disorders (12)

**Socio-Technical System Design**

**STUDY UNIT 6**

# Macroergonomics success stories

* 1. Metrics
     1. Measurement of the success of Macroergonomics intervention may address any or all process outcomes
        1. E3S3
           1. Effectiveness, Quality, Meeting customers’ expectations
           2. Efficiency, Productivity, Optimal use of Resources
           3. Ease of use, Intuitive use of the product or service (with or without facilitators) with error avoidance and mitigation
           4. Safety – prevention or mitigation of damage to system or subsystems (technology, human, environmental, organizational) due to failure of one or more subsystems or interactions between two or more subsystems
           5. Security – prevention or mitigation of system / process failure due to malicious or accidental adverse activities of human subsystem components
           6. Satisfaction – optimal satisfaction of all human stakeholders / customers.
     2. Note that there may be tradeoffs among these outcomes
     3. Metrics best communicated through outcome summary matrix (see Study unit 5)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Outcome** | **Effectiveness** | **Efficiency** | **Ease of Use** | **Safety** | **Information** | **Employee** |  |
| **Life Cycle Stage** |  | **Quality** | **Productivity** | **Complexity** | **Health** | **Security** | **Satisfaction** | **Average** |
| **Design** | **Product** | **10** | **0** | **3** | **4** | **0** | **6** | **3.8** |
|  | **Manufacturing** | **5** | **10** | **1** | **7** | **2** | **0** | **4.2** |
| **Production** | **Component** | **2** | **1** | **5** | **8** | **1** | **7** | **4.0** |
|  | **Assembly** | **7** | **7** | **9** | **0** | **7** | **2** | **5.3** |
| **Distribution** |  | **3** | **10** | **9** | **5** | **9** | **0** | **6.0** |
| **Maintenance** |  | **4** | **10** | **3** | **9** | **2** | **2** | **5.0** |
|  | **Average** | **5.2** | **6.3** | **5.0** | **5.5** | **3.5** | **2.8** | **4.7** |

* 1. E3S3 measurement

**Outcome Summary Matrix**

* + 1. Use quality circles, focus groups, customer feedback surveys, statistical analysis of quantitative outcomes to address each possible outcome
       1. use random / stratified sampling where possible
    2. Be aware of bias from different constituencies
       1. Note that different customers / stakeholders / participants may have different priorities
    3. Note that negative feedback (eg Customer complaints) is more easily generated than positive feedback (eg. Customer loyalty)
       1. Consider E-bay seller feedback ratings
    4. Use specific measures of these general outcomes where available
       1. Effectiveness, Quality, Meeting customers’ expectations
          1. Popularity in the marketplace – sales
          2. Customer complaints, warranty, independent product ratings
          3. Life cycle measures
       2. Efficiency, Productivity, Optimal use of Resources
          1. Cost relative to the competition
          2. Direct resource measures – labor, energy, materials (scrap)
       3. Ease of use, Intuitive use of the product or service (with or without facilitators) with error avoidance and mitigation
          1. Life cycle measures

Manufacturing, Use, Maintenance

Use of need for facilitators

Forgiving – error trapping, redundancy

* + - 1. Safety – prevention or mitigation of damage to system or subsystems (technology, human, environmental, organizational) due to failure of one or more subsystems or interactions between two or more subsystems
         1. Accident / incident measures – frequency, consequences

(i) Use common currency methods – Quantum Risk Analysis

* + - 1. Security – prevention or mitigation of system / process failure due to malicious or accidental adverse activities of human subsystem components
         1. Attractiveness as target
         2. Implications of security failure
         3. Incidence and severity of security lapses
      2. Satisfaction – optimal satisfaction of all human stakeholders / customers.
         1. The major management / collaborative challenge
         2. Multiple constituencies
         3. Tradeoffs

1. Use common currency Risk Benefit Evaluation
2. Use collaborative / consensus approach to evaluation
   1. Textbook



Outcome

Experience Targets

Data History Predictions

Criteria

Policy

Science

Evaluation

* Verification
* Validation
* Sensitivity

Consensus:

* HF Experts
* Engineers
* Managers
* Employees
* Customers

Consensus

* + 1. Red wing shoe company (p88)
       1. Outcome problem - Work related musculo skeletal disorders
       2. Administrative controls - Rotation, work cells etc
       3. Engineering controls - Addressed posture and force issues by design
       4. Evaluation - Major savings
    2. Telecommunications – AT&T (p89)
       1. Problems – Workers compensation costs
       2. Micro ergonomics interventions (low hanging fruit)
       3. Engineering / Administrative controls
          1. Removed conveyor paced work
          2. Job enlargement – work cells
       4. Reduced lost days injuries and workers compensation
    3. Food service system(p89)
       1. Productivity shortcomings
       2. Extensive micro ergonomics improvements
          1. Participatory approach
          2. Engineering interventions - Workplace layout, interfaces
          3. Method changes
       3. Large productivity increases – increased sales
    4. Petroleum Distribution(p90)
       1. Safety problems
       2. Participation strategy
          1. Worker initiated micro ergonomics changes
          2. Safety training
       3. Safety culture changes
       4. Reduced accidents / injuries
       5. Cost savings
  1. Quality of Work Life in Sweden
     1. Sweden seen as leader in participatory industrial processes
     2. Government Quality of Work Life organization
        1. Many industrial interventions
     3. Political cancellation of QWL institution by new government
  2. Ergonomics standard in US
     1. Introduced following specific activities by OSHA / Unions in meatpacking, automotive and nursing home industries
     2. Heavily supported by organized labor
     3. Rationale was the high prevalence (“epidemic”) of Work Related Musculo Skeletal Disorders particularly as related to the back and upper limbs
     4. Experts recruited by OSHA to develop standard
     5. NIOSH, University and Professional Society technical support
     6. Proliferation of tools and rules
     7. Rapid increase in number of ergonomists employed by industry
        1. Varied levels of training / certification
        2. Industry sponsored conferences
        3. OSHA sponsored town hall meetings
     8. Band wagon interventions by opportunists
        1. Back belts, computer work stations, chairs, tools
        2. Varied credibility / effectiveness
     9. Opposition established in US Chamber of Commerce, National Association of Manufacturers, Center for Office Technology (Computer Manufacturers)
     10. Standard Introduced by Democrats at end of their, cancelled by Republicans (George W Bush) immediately after taking office
     11. Seen as shift in locus of control to a bottom up process using WRMDSs as the reason
         1. The truth lies somewhere in the middle – productivity / efficiency pressure leads to top down short cycle work. Interventions to reduce posture and force factors, but repetition factors increase. Unions resist job rotation based on traditional seniority based job choice.
         2. Some psychosocial and political overlays confound the issue
         3. An ideal Socio Technical System participative approach could address the issue, but historical attempts have had relatively short lived success (Volvo, Saturn etc.)
         4. Management reluctant to share management responsibilities with employees
  3. Saturn
     1. Partially successful for 15 years
     2. Joint Union / Saturn management
     3. Team structure with rotation
        1. Approach sometimes defeated by medical restrictions
     4. Poor shift system – one week rotation
     5. No integration of design at plant location – still tied to GM engineering
     6. Innovative design – entry level vehicle, plastic panels, skillets in general assembly
     7. Product failed in the marketplace eventually
     8. National union infiltration
     9. Saturn becomes another division of GM
     10. Saturn line discontinued

# Formal studies of group activities

1. Joint optimization – personnel and technology (plus environment and organization)
   1. Department performance improved by joint optimization (60/40)
2. Formalization in planning
   1. Compared to down structured processes with less formal approaches
   2. No statistical differences
   3. Compare with “Naturalistic decision making”
3. Facilitation
   1. Improved participation by group members
   2. Did not improve performance
   3. Facilitated brainstorming groups produced more ideas
4. Decentralized quality control
   1. Push QC down to the line, using Quality Circles and Statistical QC charts (visual controls)
   2. Indicated that more elaborate 3D charts may not work – “naïve realism”
5. Engineering design groups
   1. Product development teams
   2. Concurrent engineering
   3. Horizontal differentiation
   4. Experimental investigations not conclusive
   5. In practice CE works, provided there is not too much formalization and opportunities for some independent sub group activities.
      1. “Throwing the design over the wall”
         1. Battery location, Intermediate shaft, wind shield wiper motor, brake booster
   6. Larger groups more costly than smaller groups
   7. No significant value of group mediation technology
6. Virtual group behavior and performance now shows considerable success in distance learning
   1. Mediation needed
   2. Grading reliability challenges

# Future directions of STS

* 1. International companies
     1. Central responsibility for work system structures
     2. Local responsibility for micro process design
  2. Global labor forces
     1. Wage rates much lower in developing countries
     2. Imported labor – Central America, Southern / Eastern Europe, India
     3. Paternalism – community support
        1. Automobile manufacturing in US southern states
        2. Demise of Flint and Pontiac
  3. Transportation costs
     1. Components – many are made on high rate production lines in third world countries
     2. Finished products – proliferation of container vessels
        1. Energy costs borne by customer
  4. Customer locations
     1. Changing from US and Europe to producer nations – China, India
  5. Environmental issues
     1. Energy sources
        1. Fossil fuel, sun, wind, water
     2. Global warming
        1. Transportation
        2. Manufacturing
     3. Waste and packaging
     4. Water
        1. Dams, reservoirs, desalination
  6. Information technology
     1. Major effect on industry
        1. Computer control of processes
           1. Software reliability and safety issues
        2. Data capture and analysis
           1. Corporate now has all the data

E.g. data capture in gas and oilwell drilling

* + - 1. Internet
         1. Information access – enormously available and rich source on almost any subject
         2. Teleconferencing – Now commonplace for both synchronous and asynchronous communications with Skype, Facebook etc.
         3. Telemarketing – from television to mobile devices to computer pop ups.

Marketing directed to individuals based on their web surfing behaviors

* + - * 1. Control of the Internet – censorship
        2. Distraction and productivity
    1. International spread / subcontracting of software development, call centers etc
  1. Litigation
     1. Product design failures
        1. Considerable rise in “usability” concepts before and after the event
     2. Medical error
        1. Major design of product and procedure challenges
     3. Consumer products
        1. Foreseeable misuse
  2. International companies
     1. International standards Litigation
        1. Lead based paint, toys, pet food
        2. Pesticides
        3. Bhopal
        4. Exxon Valdes
     2. National standards and regulations
     3. WHO and ILO influence on product and manufacturing safety
        1. Lead based paint

# Conclusions

* 1. STS design plausible but threatens traditional organizational design models
  2. Seen sometimes as politically motivated by the disenfranchised
  3. Reversion to informal and formal hierarchies as organization matures



**READ:**

1. *Chapter 6 – Macro Ergonomics Results*
2. *Chapter 7 – Future Directions in Macro Ergonomics*



**EXERCISE:**

a) Project reports – cafeteria design

# Self Test Questions

a) Create a one page report describing the advantages and disadvantages of the socio technical systems approach to the design of a complex organization with which you are familiar.